Ministry of Education
Ontario

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8-HEC
373.1909713
O59DE/C-S
Box 4

Curriculum Guideline

Science

Intermediate and
Senior Divisions
1988

Part 11

Geology

Grade 12, General and
Advanced Levels

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Introduction

The Parts of the Guideline

This document is Part 11 of a fifteen-part curriculum guideline that outlines the science program for the Intermediate and Senior Divisions in Ontario schools and describes the science courses that can be offered (see the list of courses and their course codes in Appendix A). The term *guideline* refers to the entire set of fifteen parts.

This part must be read and implemented in conjunction with Part 1, *Program Outline and Policy*. When implementing the courses that are described in this document, teachers are to incorporate the many policies and features outlined in Part 1, which will enable them to interpret the overall intent and expectations of the Ministry of Education in the science program. The table of contents for Part 1 is given in Appendix B at the end of this document so that the reader may have ready access to the list of chapters and topics therein.

The provincial science program for the Intermediate and Senior Divisions comprises the courses described in Parts 2 to 15. These come under the framework and policy set forth in Part 1. The entire science guideline consists of the following fifteen parts:

Part 1:	Program Outline and Policy
Part 2:	Science, Grades 7 and 8
Part 3:	Science, Grades 9 and 10, General Level
Part 4:	Science, Grades 9 and 10, Advanced Level
Part 5:	Science, Grades 9 and 10, Basic Level
Part 6:	Science, Grades 11 and 12, Basic Level
Part 7:	Environmental Science, Grades 10 to 12, General Level
Part 8:	Environmental Science, Grades 10 and 12, Advanced Level
Part 9:	Applied Biology and Applied Chemistry, Grade 11, General Level
Part 10:	Applied Physics and Technological Science, Grade 12, General Level
Part 11:	Geology, Grade 12, General and Advanced Levels
Part 12:	Biology, Grade 11, Advanced Level, and the OAC
Part 13:	Chemistry, Grade 11, Advanced Level, and the OAC
Part 14:	Physics, Grade 12, Advanced Level, and the OAC
Part 15:	Science in Society, OAC

The chart on the next page indicates the twenty-eight science guideline courses that may be offered in Grades 7 to 12 and at the OAC level.

Policies and Features That Apply Across the Science Program

Part 1 of the guideline specifies a great number of the policies and features that are to be integrated into the design of the science program in the Intermediate and Senior Divisions. There are too many of these to describe them in full in each of Parts 2 to 15, but the following points will give the reader some idea of the scope that is involved. They include:

- information about the science credits that are required for the earning of the Ontario Secondary School Diploma;
- a list of science courses that are prerequisite to other science courses;
- the policy regarding mandatory student activities in the science laboratory;
- a list of the aims of the science curriculum and the various emphases that may be used to blend these aims with scientific content;
- policy governing time allocations for units of study and the order in which core and optional units may be taught;
- stipulations about locally designed units;
- suggestions about preferred routes that students might take through the science program in a secondary school;
- recommendations related to exceptional students, individualized instruction, life-management skills, career awareness, the role and evaluation of language in science courses, and a balanced perspective on the role of both girls and boys in science;
- recommendations on the introduction and handling of sensitive issues;
- specific suggestions about resources for the teaching of science;
- ideas about different modes of delivering science courses, including the co-operative education mode;

Authorized Science Guideline Courses, Intermediate and Senior Divisions

	Basic Level	General Level	Advanced Level
Grade 7		Science	
Grade 8		Science	
Grade 9	Science (SNC1B)	Science (SNC1G)	Science (SNC1A)
Grade 10	Science (SNC2B)	Science (SNC2G) Environmental Science (SEN2G)	Science (SNC2A) Environmental Science (SEN2A)
Grade 11	Science (SNC3B)	Applied Biology (SBA3G) Applied Chemistry (SCA3G) Environmental Science (SEN3G)	Biology (SBI3A) Chemistry (SCH3A)
Grade 12	Science (SNC4B)	Environmental Science (SEN4G) Geology (SGE4G) Applied Physics (SPA4G) Technological Science (STE4G)	Environmental Science (SEN4A) Geology (SGE4A)* Physics (SPH4A)
OACs			Biology (SBI0A) *Prerequisite* – Biology (SBI3A) Chemistry (SCH0A) *Prerequisite* – Chemistry (SCH3A) Physics (SPH0A) *Prerequisite* – Physics (SPH4A) Science in Society (SSO0A) *Prerequisite – One of:* Biology (SBI3A) Chemistry (SCH3A) Environmental Science (SEN4A) Geology (SGE4A)* Physics (SPH4A)

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*Since the Grade 12 advanced-level geology course described in this document may be taught under the aegis of a geography department as Geology (GGE4A) – note the course-code change – then either Geology (SGE4A) or Geology (GGE4A) may count as a prerequisite to Science in Society (SSO0A).

- policy pertaining to the significant role to be played by measurement and metric units in science courses;
- stipulations related to the treatment of symbols, significant digits, and mathematical problem solving;
- recommendations concerning the roles to be played by calculators and computers in science courses;
- specific directions about safety;
- policy and principles pertaining to the evaluation of student achievement;
- policy regarding differences in the treatment of science courses at the three levels of difficulty;
- many suggestions about implementing the science program.

It cannot be emphasized strongly enough that teachers of science must integrate the policy and recommendations outlined in Part 1 with the teaching of science and cannot simply rely on the course descriptions given in Parts 2 to 15 of the guideline.

The Science Curriculum Continuum

By the time students have reached the Senior Division, they will have experienced first a *unified* approach in the Primary and Junior Divisions, in which science is related to a number of other subject areas, and then a *diversified* approach to a mosaic of science disciplines – biology, chemistry, physics, and environmental science – in the Intermediate Division. In the Senior Division they are provided with a *specialized* approach, in which the science courses deal with a single discipline at a time.

Although these approaches – unified, diversified, and specialized – provide different ways of dealing with the subject, the intention is to ensure that there is a continuum throughout the years. The two courses in geology outlined in this document build on the physical-science units of the courses in the Intermediate years.

In all science courses the core units and the prescribed number of optional units, if any, are to be included. The time allocation for each unit of study should act as a guide in helping teachers devote an appropriate amount of time to each of the units in a course. This is important in view of the continuum from one course to another and to postsecondary science programs.

Compulsory and Prerequisite Courses

In the secondary school program, two science courses are required among the compulsory subjects that are necessary for the earning of the Ontario Secondary School Diploma. It is, therefore, anticipated that most of the students who enrol in the Senior Division geology course will have taken Grade 9 and 10 science.

Curriculum Emphases

It is recommended that teachers organize each of the courses described in this document around a particular curriculum emphasis or set of emphases. Such emphases give the curriculum a special focus that can be introduced in addition to the content and processes outlined in the courses. This approach is discussed in subsection 3.4, "Curriculum Emphases – Blending Curriculum Aims With Content", of Part 1 of the science guideline. A list of emphases is given in table 2 of that subsection. These emphases will enhance the development of the science courses described in this document. A particular emphasis that is stressed throughout an entire course or for one or more units at a time needs to be highlighted so that it becomes a focal or integrating theme.

Student Activities

In each unit of study there is a section entitled "Student Activities". This section indicates the *mandatory* laboratory activities required of students. Teachers may substitute *equivalent* laboratory activities where appropriate. Those activities that are actually to be performed by students themselves are marked with asterisks. If time and circumstances permit, the teacher should encourage students to do some or all of the unmarked activities as well. However, such activities may be demonstrated by a student or the teacher or may be discussed in conjunction with a textbook, film, computer program, or other learning material used as a resource. In any event, the scientific concepts and principles related to such unmarked activities and identified in the objectives of the unit of study shall be considered to be part of the prescribed course.

Generally, the best approach to the teaching of science is to ensure that the content develops directly from related student activities. In each unit of study the skills and processes of scientific work should usually be presented as the central component, from which the subject matter, applications, and implications emerge.

Safety

Safety awareness must be developed in all science students. Constant attention to accident prevention is to be stressed in all student activities and teacher demonstrations in the laboratory. Section 9, "Safety", in Part 1 of the science guideline contains the following comprehensive subsections:

- Safety in the Laboratory
- Some Recommended Safety Procedures
- Animal Care in Science Courses
- The Safe Use of Plants

In each unit of study, subsection 6, "Safety Considerations", acts as a reminder of some of the safety features that pertain to the unit in question. General reference, however, should constantly be made to the safety section in Part 1. In addition, schools must always remain on the alert in regard to safety and must maintain an up-to-date safety-awareness program. For example, this guideline does not outline all precautions regarding field trips.

Sensitive Issues

The curriculum outlined in this science guideline places a distinct emphasis on the science-technology-society connection. For this reason scientific applications and societal implications are mandatory components of each unit of study. In addition, Part 1 of this guideline underlines the need to incorporate morals/values education into science courses. Undoubtedly, this will give rise to the discussion of some sensitive issues.

Such discussions are important. Generally, they should be focused and should provide an open forum for the expression of different viewpoints. In this regard teachers of science are urged to familiarize themselves with section 10, "Values in Science Education", of Part 1 of the guideline and to pay particular attention to the principles to be observed when dealing with sensitive issues in the science curriculum. These principles are mentioned in subsection 10.2 of Part 1.

Locally Designed Units

Among the optional units in each of the courses described in this document is one entitled "Locally Designed Unit" (LDU). Such a unit is included to allow teachers, at their discretion, to introduce an appropriate new area of geology not described in the guideline, to expand on previous units or topics by adding new work, or to use the time allocated to the LDU to extend the time allocations for the core units. (See also Part 1, subsection 5.5.)

Evaluation of Student Achievement

In each unit of study described in the courses outlined in this document, section 5, "Evaluation of Student Achievement", specifies certain items that must be included in students' term marks (exclusive of formal examinations) when their achievement is evaluated. In most units teachers are required to evaluate students' activities and related laboratory reports. However, the proportion of the mark assigned will vary from one teacher to another. In order that the experimental component of science be emphasized, the overall mark for an entire science course must include at least 15 per cent for the evaluation of student achievement in laboratory skills and reports.

Cross References

In the descriptions of each unit of study outlined in this document, cross references are provided in parentheses. These are included to provide some examples of the relationships that exist among the parts of the unit.

Particular Features of the Senior General- and Advanced-Level Geology Courses

Units of Study and Their Time Allocations

The following charts provide an overview of the units of study in the Grade 12 general-level and the Grade 12 advanced-level geology courses. They also indicate the time to be allotted to each unit.

Geology, Grade 12, General Level (GGE4G/SGE4G)

Units of Study	Time Allocations
Core	
1. A Geological Survey of the Earth	3 h
2. Minerals: Building Blocks of the Earth	18 h
3. Rocks: Materials of the Earth's Crust	18 h
4. Records in the Rocks	16 h
5. The Dynamic Earth	15 h
6. Case Studies in Geology	15 h
7. Economic Geology	15 h
8. Environmental Geology	10 h
	110 h

Geology, Grade 12, Advanced Level (GGE4A/SGE4A)

Units of Study		Time Allocations
Core		
1. Planet Earth		3 h
2. Minerals		18 h
3. The Earth's Crust: Rocks		16 h
4. The Dynamic Earth		18 h
5. The Record of Life		14 h
6. Clocks for the Rocks		5 h
7. Geological Maps and Illustrations		6 h
8. Environmental Geology		7 h
9. The Ontario Record		5 h
		92 h
Optional		
Three of:		
1. The Precambrian Shield	6 h	18 h
2. Paleozoic Rocks	6 h	
3. Glacial Terrain	6 h	
4. The Great Lakes	6 h	
5. Drainage Basins	6 h	
6. Ground Water	6 h	
7. Geophysical and Geochemical Exploration	6 h	
8. Extraterrestrial Geology	6 h	
9. Locally Designed Unit	6 h	
		110 h

Some Teaching Suggestions

The Grade 12 geology courses emphasize a balance between substantive content and scientific process and involve both quantitative and qualitative work. Quantitative work is accomplished through visual analysis and measurement, while qualitative work is achieved through the oral and written communication of ideas, concepts, findings, questions, and opinions. The balance between quantitative and qualitative work will vary from the advanced to the general level.

The organization of the general-level course is different from that of the advanced-level course. The main difference is that there are fewer units in the former, and options are offered within these core units. The direction, coherence, and relevance of both courses should be obvious to students from their design and sequence.

The general-level course is divided into eight units. Units 1 to 4 must be taught first and in order, as they deal with the fundamental elements of geology – the earth, minerals, rocks, and fossils. These units are a prerequisite for units 5 to 8. The title of each of these latter units indicates a common theme for a number of optional topics found within the unit. These units may be taught in any order.

The identification of applications and societal implications in each unit of study should ensure that students perceive geology as a relevant human endeavour that influences lives, societies, and nations.

Reference should be made in the advanced course to the study of geology in university, and students in general-level courses should be made aware of technical programs related to geology that are offered by Ontario's colleges of applied arts and technology. Mention should be made of the career opportunities for geologists and geotechnicians, as well as other opportunities for employment. The achievement of Canadian and other geologists should be stressed from time to time.

Geology courses may be offered by the geography or the science department. A student selecting geology as an elective course has the opportunity of designating such a credit as *either* a science credit *or* a social science credit *but not both*. If the credit is in science, the course code is SGE, and if it is in geography, the code is GGE.

In geology field trips provide a theatre for teaching and an excellent learning environment for students. The geology teacher should take advantage of every opportunity to have students conduct field investigations, whether for a full-day outing or a one-period simulation. All field trips must be properly prepared for in the classroom prior to departure and assessed in the classroom on completion. The field trip should not be used solely for enrichment but should be included, where possible, as an integral part of the course. Normal safety precautions must be taken in road cuts and other geological environments.

Advantage should be taken of the expertise of individuals in the local area who work in businesses and professions related to geology. They can provide invaluable assistance to the geology student and teacher.

Most science and geography departments will have support materials to begin a geology program. However, it may be necessary to purchase some additional materials. For example, class sets of the following will prove useful: rulers, protractors, pencil crayons, hand lenses, streak plates (unglazed porcelain), concrete nails (for hardness tests), small magnets, eye-drop bottles (for dilute hydrochloric acid). In addition, mineral collections, rock collections, and fossil collections can be assembled by the teacher, the geography or science department, or students themselves. The following are other supplies that can be purchased, constructed, or collected: geological maps and illustrations, mineral and rock display samples, goniometers (for measuring cleavage angles), models, slides, and photographs. Over time geology teachers should attempt to upgrade the quantities and quality of the demonstration specimens used for display and the geologic equipment used by students.

Geology, Grade 12, General Level
(GGE4G/SGE4G)

Core Units

- A Geological Survey of the Earth
- Minerals: Building Blocks of the Earth
- Rocks: Materials of the Earth's Crust
- Records in the Rocks
- The Dynamic Earth
- Case Studies in Geology
- Economic Geology
- Environmental Geology

(110 hours)

Core Unit 1

A Geological Survey of the Earth

Time: 3 hours

The purpose of this unit is to introduce students to a study of the earth from a geological perspective. Theories of the earth's origins and age will be examined within this perspective. Students should be encouraged to evaluate the role and the limitations of the proposed theories and to distinguish between facts and inferences.

This unit may be divided into topics such as the following:

- Geology as a field of study: an overview
- The structure of the earth
- Theories of the earth's age
- Theories of the earth's origin

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the historical development of geology (7b);
b) an appreciation for the immensity of geological time (2d, 2h);
c) a questioning attitude regarding views on the origin of the earth (2d, 2h);
d) a curiosity about the power of natural phenomena (4a, 8f);
e) an open-mindedness towards investigations related to the earth;
f) an appreciation of the mobile nature of the earth's crust (2f);
g) an appreciation of the usefulness of theories (3b, 4b);
h) an appreciation of the differences between the origin, development, and nature of scientific theories and other non-scientific modes of explanation (2d, 2h, 8g).

Skills. Students will have the opportunity to develop skill in:

a) observing and making inferences about the dynamic nature of the earth (2d);
b) graphing geological data (2g);
c) developing a model of the internal structure of the earth based on the refraction and reflection behaviour of P- and S-waves as they pass through the earth (2e);
d) calculating the age of rock and mineral samples (8b);
e) making inferences about the origin of the earth, the solar system, and the universe on the basis of a variety of observations (2d, 2h);
f) using the library and other sources of information to obtain relevant information about theories of the age and origin of the earth (2h);
g) abstracting information from reading selections on the earth's age and origins and identifying the main ideas, the argument sequence, and the author's point of view (2d, 2h, 7b);
h) analysing knowledge claims by distinguishing between facts and inferences (8g);
i) analysing and evaluating data (2a, 2b, 2g).

Knowledge. Students will be expected to:

a) define the following terms: geology, half-life, galaxy, light year, inner and outer planets, protoplanet, seismology, shadow zones, asthenosphere, lithosphere, the Mohorovičić, convection current, plate, spreading centre, subduction zone;
b) describe the dust-cloud theory for the origin of the earth (2c);
c) list the evidence that supports the "big bang" theory of the origin of the universe (2d);
d) describe Hutton's law of uniformitarianism and state its importance to an understanding of the earth's history (7b, 8g);
e) make calculations regarding the age of a rock or mineral sample (8b);
f) calculate the average geothermal gradient of the earth and define and give examples of sea-floor spreading and plate subduction (2g, 8a);
g) outline how shadow zones, the Mohorovičić, and meteorites contribute to geological inferences about the earth's interior structure (2e);
h) list evidence of a dynamic earth (2f).

2. Student Activities

Students are to:

*a) determine the age of a rock or mineral, using the principles of radioactive decay (8a, 8b);
b) construct a linear graph, positioning inner and outer planets;
*c) draw profile sketches that illustrate the dust-cloud theory;
d) report on theories of the origin of the earth, the solar system, or the universe (8g);
*e) draw a profile of the earth, illustrating and outlining shadow zones of P- and S-waves as they travel through the earth's interior (4b);
*f) construct a summary chart that lists major physical characteristics of the earth's internal structure (8a);
g) calculate the earth's geothermal gradient (from temperature-depth well-log data);
*h) present various scientific theories regarding the origin of the earth and the universe (8e).

3. Applications

a) Education and training for careers in geology are available to students at the community colleges and universities.
b) Geology plays a key role in any study of the earth.

4. Societal Implications

a) A knowledge of geologically active zones can aid in disaster prevention.
b) Societies may present and interpret natural phenomena in geological terms.
c) Geology plays a key role in Ontario's economy.

5. Evaluation of Student Achievement

At least 20 per cent of the term mark for this unit is to be based on students':

a) drawings of diagrams;
b) participation in class discussions;
c) graphing and calculation skills.

6. Safety Considerations

There are no special safety considerations for this unit.

7. Possible Extensions

Some students might:

a) determine the career and postsecondary educational opportunities that are available to students who have completed a general-level geology course;
b) research the contributions made to the field of geology by famous nineteenth-century naturalists and twentieth-century geological scientists.

8. Some Teaching Suggestions

a) The role of theories in science should be emphasized in this unit.
b) The following formula could be used for calculating the radioactive age of a rock sample:

$$\text{decay fraction} \times \text{half-life} = \text{radioactive age}$$

where the decay fraction is equal to

$$\frac{\text{weight of daughter element}}{\text{total weight of parent radioactive element}}$$

c) Guest speakers can provide an invaluable means of presenting career information and of making the subject relevant to students of this course.
d) A variety of audio-visual materials can be used to emphasize and reinforce ideas related to the earth's geological dynamism and origin.
e) Group work and co-operative discussions should be encouraged.
f) The treatment of plate tectonics in this unit should be approached in a way that will enable students to see plate tectonics as a unifying geological theory.
g) Students should be provided with opportunities to evaluate their personal beliefs by listening to, reading, and evaluating evidence that may be in agreement with, or contrary to, their own values and opinions.
h) Since students may hold alternative points of view regarding the origins of the earth, theories of the origin and age of the earth should be treated with appropriate sensitivity. If alternative points of view are raised, the policy and suggestions outlined in subsection 10.2, ''Handling Sensitive Issues'', of Part 1 of this guideline are to be followed.
i) Theories of the origin and age of the earth may be used to illustrate some of the characteristics of the nature of science (see subsection 3.2 of Part 1 of this guideline).

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*See the subsection entitled ''Student Activities'' on page 5.

Core Unit 2

Minerals: Building Blocks of the Earth

Time: 18 hours

The purpose of this unit is to introduce students to the study of minerals. The economic importance of minerals, as well as their aesthetic qualities, are emphasized. The focus of the unit is on the development of skills that will enable students to identify minerals.

This unit may be divided into topics such as the following:

- Minerals as components of rocks
- Properties of minerals

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the beauty of minerals (3);
b) a curiosity as to how minerals are formed and identified (2a, 2n);
c) an appreciation of the consistency of some physical and chemical properties of minerals (8b);
d) an appreciation of the importance of minerals to modern industrial society (4d).

Skills. Students will have the opportunity to develop skill in:

a) using a contact goniometer and hand lens to determine the streak, transparency, lustre, tenacity, hardness, cleavage and fracture, crystal form, and density of a mineral (2a, 2n);
b) determining the special properties exhibited by some minerals (2l, 6a);
c) identifying at least nine common rock-forming minerals (2a, 2n);
d) observing the special effects of ultraviolet light on some minerals;
e) conducting an experiment to determine the density of several minerals;
f) performing simple examinations of minerals that exhibit outstanding properties related to taste, smell, touch, magnetism, and refraction of light (8a, 8c);
g) performing a laboratory examination of at least nine common rock-forming minerals, employing mineral-property testing techniques (8b).

Knowledge. Students will be expected to:

a) define the following terms: element, chemical compound, mineral, native mineral, rock, mineral property, mineral colour, streak, transparency, lustre, tenacity, cleavage, crystal form, fluorescence, phosphorescence, relative hardness, absolute hardness, monominerallic and multiminerallic rocks (2a, 2n);
b) list the eight main elements in the earth's crust (2c);
c) explain the economic use of selected rock-forming minerals (8b);
d) describe the molecular structure of a mineral such as halite as it applies to the cleavage concept (2k);
e) distinguish between a crystal surface and a cleavage surface (2d, 2j);
f) compare the advantages of streak over mineral colour as an identifying property (2d, 2e);
g) relate the importance of a mineral's relative hardness to that of its absolute hardness (2i).

2. Student Activities

Students are to:

*a) use a hand lens to examine and describe the mineral grains that compose a monomineralic rock (size, shape, brittleness/softness, colour, surface configuration, and degree of reflectivity);
*b) conduct a hand-lens examination of crushed material derived from a multimineralic rock such as granite and describe each mineral in the same fashion as in activity 2a;
*c) construct a flow chart that illustrates the relationships among elements, chemical compounds, minerals, and monomineralic and multimineralic rocks;
*d) examine the variety of colours that a mineral family may exhibit (8a);
*e) use a streak plate to test for a mineral's streak;
*f) examine the ability of selected minerals to transmit light;

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*See the subsection entitled "Student Activities" on page 5.

g) arrange a series of minerals in ascending order of relative hardness;
*h) use Moh's scale to determine a mineral's relative hardness;
i) compare the relative and absolute hardness of Moh's minerals, using a graphic form;
*j) cleave mineral hand samples, noting the differences in appearance between cleavage and fracture (6b);
*k) study a molecular model of a mineral such as halite, noting the meaning of concepts such as cleavage plane(s), angle, and fracture;
*l) cleave samples of mica and galena, note the differences between perfect and step cleavage, and illustrate these differences with diagrams;
*m) measure cleavage angles, using a contact goniometer;
*n) perform examinations of selected minerals, noting the following for each of them: mineral number of cleavage planes, angle value, type, presence or absence of fracture.

3. Applications

An understanding of the physical and chemical properties of minerals results in the important economic uses of many minerals.

4. Societal Implications

a) The physical and chemical properties of minerals have an immense impact on the nation's economy and on every Canadian's way of life.
b) The mining and processing of minerals involve safety hazards.

5. Evaluation of Student Achievement

Since the emphasis in this unit is placed on the development of skills in mineral-testing procedures, at least 60 per cent of the term mark for this unit is to be based on students':

a) ability to perform mineral-property tests on hand samples;
b) laboratory reports;
c) summary laboratory test on mineral identification(2a, 2n).

6. Safety Considerations

a) Students should be cautioned on the proper use of dilute hydrochloric acid for the carbonate test; all samples on which acid has been used should be rinsed thoroughly.
b) Students must wear safety glasses when cleaving minerals with a hammer and chisel.
c) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) perform a lapidary project with minerals;
b) visit the mineralogy gallery at a local museum or an assayer laboratory;
c) discuss the environmental problems associated with mining;
d) develop a class collection of minerals.

8. Some Teaching Suggestions

a) If at all possible, student mineral specimens that clearly and appropriately exhibit mineral-property features should be used.
b) The following rock-forming minerals could be used for identification purposes: quartz, orthoclase feldspar, plagioclase feldspar, biotite mica, muscovite mica, olivine, garnet, calcite, augite, pyrite.
c) Slides, films, and video presentations can be used to reinforce the property concepts learned in class.

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*See the subsection entitled "Student Activities" on page 5.

Core Unit 3

Rocks: Materials of the Earth's Crust

Time: 18 hours

The purpose of this unit is to introduce students to the study of rocks. The unit focuses on the classification of rocks. The problems of classifying rocks according to properties are described, and a rationale is provided for classifying rocks according to formation.

This unit may be divided into topics such as the following:

Igneous rock
Sedimentary rock
Metamorphic rock

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation that rocks represent one of the earth's primary components (2c, 3c);
b) an appreciation of the significance of rocks as a primary source of industrial materials (3b, 4c);
c) a curiosity about rocks as records of the earth's history (2f);
d) an appreciation of the rock cycle as a revolving, dynamic circle of petrogenesis and consequent petrologic alteration (3c).

Skills. Students will have the opportunity to develop skill in:

a) identifying rock samples and using petrographic equipment (2a, 2g);
b) observing and making inferences (both qualitative and quantitative) about rock samples (2a, 2g);
c) performing comparative analyses of different rock samples (2a, 2f, 2g);
d) drawing illustrations and diagrams that reflect observations they have made during laboratory analyses of rock samples (2e);
e) identifying the mineralogical composition of rock samples (2g, 8b);
f) using measuring devices, hand lenses, and microscopes as aids to observation (2b, 2c, 7c);
g) classifying rocks according to information derived from the analysis of petrographic properties (2b, 2f, 2g).

Knowledge. Students will be expected to:

a) define and illustrate the following geological terms: lava, magma, volcanic rock, plutonic rock, igneous texture, petrology, magmatic differentiation, igneous intrusive structures (dyke, sill, etc.), porosity, permeability, evaporite, precipitate, sorting, foliation, metamorphic grade, metamorphic texture (2a, 2g);
b) explain how texture assists in the classification of an igneous rock as either volcanic or plutonic (2d);
c) list the petrological characteristics of the three main classes of rocks and relate them to the formation of each class (2b, 2f, 2g);
d) describe the roles of water, pressure, and temperature in the formation of metamorphic rocks (2g);
e) identify selected rock samples according to common mineralogical composition (2b, 2f, 2g);
f) differentiate between contact and progressive regional metamorphism (2g);
g) distinguish among sedimentary rock subclasses (clastic, organic, and chemical) (2f);
h) identify the following: (i) igneous rocks: scoria, obsidian rhyolite, granite, pegmatite, basalt, porphyry, gabbro, pumice; (ii) sedimentary rocks: conglomerate, sandstone, shale, fossil limestone, chalk, bituminous coal, rock salt, potash; (iii) metamorphic rocks: quartzite, slate, schist, marble, gneiss.

2. Student Activities

Students are to:

*a) examine the appearance, form, and composition of two contrasting igneous rocks (e.g., obsidian and granite);
*b) using a hand lens, examine and sketch various igneous volcanic and plutonic rock samples to determine differences in the size and arrangement of similar mineral crystals in each sample (3b);
*c) observe and identify igneous structures from illustrations and landscape scenery;

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*See the subsection entitled "Student Activities" on page 5.

*d) examine at least eight igneous rocks, describing each according to subclass, colour, texture, mineral content, and outstanding characteristics (4c);
*e) using a hand lens, examine and sketch a sedimentary rock commonly found in the local area;
*f) examine a suite of sedimentary rocks that are representative of all sedimentary subclasses (i.e., clastic, organic, and chemical) (3d, 4b);
*g) analyse selected metamorphic rocks, noting identifiable mineral composition, texture, and degree of metamorphism.

3. Applications

a) A knowledge of rock types and rock structures developed through geological processes provides an insight into potential mineral deposits.
b) A knowledge of rock composition is important in the choice of building materials in the construction industry.
c) A knowledge of rocks provides an insight into the earth's history, which is essential to solving geological problems.
d) An awareness of weathering processes, particularly in urban areas, can provide an insight into preventative measures.

4. Societal Implications

a) It is essential that toxic chemical and nuclear-waste-disposal sites in bedrock be chosen with caution (2f).
b) Controls on quarry development and rehabilitation are examples of attempts to maintain landforms.
c) Industry is very dependent on various rock resources. It is essential that exploration in the field and laboratory research continue (2b, 2f, 2g).

5. Evaluation of Student Achievement

At least 60 per cent of the term mark for this unit is to be based on students':

a) development and interpretation of graphs where required;
b) identification of rocks from samples provided;
c) practical laboratory work;
d) laboratory reports and contributions to group activities.

6. Safety Considerations

a) Students must wear protective eyewear when chipping or fracturing rocks in the laboratory and when using acid.
b) Students should be cautioned on the proper use of diluted hydrochloric acid for the carbonate test.
c) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) investigate the composition of crushed rock or sand by determining the percentage mass and volume of each component;
b) observe the relationship between settling time and particle size through experimentation;
c) analyse the mineral content of selected rocks, using thin sections and a microscope;
d) perform experiments to examine the two main types of weathering – mechanical and chemical.

8. Some Teaching Suggestions

a) It is recommended that core unit 2 be taught before this unit so that students have an understanding of the common rock-forming minerals before beginning this unit.
b) Samples of rocks with similar mineralogical compositions should be used for the study of igneous rock texture (2d).
c) Students can better understand the concept of progressive metamorphism if they can examine representative samples from low-grade to high-grade metamorphism (2f).
d) Group work in laboratory activities should be encouraged.
e) Students should be encouraged to classify and identify rock samples (i.e., "mystery rocks") that they bring to class.
f) A field trip to examine the materials that make up the earth's crust provides students with ideal opportunities to apply their knowledge and skills at a practical level (6a, 6c).

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*See the subsection entitled "Student Activities" on page 5.

Core Unit 4

Records in the Rocks

Time: 16 hours

This unit focuses on one kind of evidence that is used by scientists to develop theories relating to the origins and history of the earth. Earth scientists use evidence found in the rocks as a basis for developing theories about what the earth was like prior to human existence. In addition to making students aware of the evidence, the unit focuses on the way in which this evidence is used to develop theories and on the usefulness and limitations of the theories as analysed from the perspective of the evidence. Students will investigate the structure and composition of igneous and metamorphic rocks, including the fossils contained in sedimentary rocks, as well as geological time and the contributions of relative and absolute (chronometric) dating techniques.

This unit may be divided into topics such as the following:

- Igneous rocks
- Sedimentary rocks
- Metamorphic rocks
- Fossil records
- The geological time scale

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a curiosity about events in the earth's geological history (3e);
b) an appreciation of the contributions of the records in the rocks to the study of geological history (3b, 3e);
c) an appreciation of how scientists use certain types of igneous and metamorphic rocks to make inferences about geographical features of the past (4a);
d) an appreciation of the incompleteness of the stratigraphic record (3f);
e) an appreciation of the role of fossil evidence in the development of theories of the earth's age and history (4a);
f) an appreciation of the usefulness and limitations of the theories based on geological evidence (8l);
g) a curiosity in regard to the collecting of fossils (8h, 8j);
h) an appreciation of the role of fossils in the development of theories related to depositional environment and paleoclimates (4d);
i) an appreciation of the role of the fossil as a tool used by geologists to correlate sedimentary strata from different geographical locations (3c, 8k);
j) an appreciation of the concept of geological time (4a);
k) an appreciation of how marked changes in the fossil record were used to construct a scale of geological time (3e).

Skills. Students will have the opportunity to develop skill in:

a) analysing on-site or sample rocks that contain fossil records (2a);
b) relating certain types of metamorphism and metamorphic rocks to the former existence of mountain belts (2b);
c) identifying and understanding sedimentary rock features, such as rain prints, mud cracks, and cross bedding (2d);
d) identifying the various ways in which preservation occurs in nature (2a);
e) recognizing and identifying by hand, both from whole specimens and fragments, a few of the more common fossils found in sedimentary rocks (2a);
f) identifying some significant forms of life over geological history (8g);
g) analysing geological sections and identifying time sequences and unconformities (2b).

Knowledge. Students will be expected to:

a) explain the meaning and significance of the following terms: paleomagnetism, radiometric dating, rain prints, mud cracks, red beds, fossiliferous limestone (8a);
b) explain how rates of sedimentation can be used to calculate age (8b);
c) explain the meaning of the following terms: unconformity, hiatus, superposition, uniformitarianism, paleontology, fossil, paleontologist (2b);
d) explain the meaning of the following terms as they apply to preservation: petrification, replacement, carbon film, casts, moulds (8e);
e) describe the processes by which organisms were preserved in rocks (8e);
f) distinguish between soft-body and hard-body preservation and between vertebrate and invertebrate fossils (3b, 8e);

g) describe and sketch the following important fossils: brachiopods, trilobites, coral, gastropods (e.g., snail), pelecypods (e.g., clam), cephalopods (e.g., nautilus), bryozoa, crinoids (8g);
h) differentiate between relative and chronometric (absolute) time (2b, 8b, 8l);
i) explain how scientists use the fossil record to illustrate a pattern of life through time;
j) explain how unconformities in rocks relate to the geological time scale;
k) explain the meaning of the following terms as connected with the geological time scale: eon, era, period, epoch.

2. Student Activities

Students are to:

*a) perform laboratory exercises that deal with stratified rocks or fossils and that include sketches or field studies;
*b) use sequential diagrams to apply the principal of superposition to stratigraphic sequences;
*c) perform simple correlation exercises in the laboratory;
*d) obtain information dealing with a paleontological topic;
*e) compare geological history and human history.

3. Applications

a) Sedimentary rocks, both in subsurface and surface exposures, are usually correlated on the basis of their lithology and fossils.
b) Special methods are employed to preserve the specimens that are used by scientists to develop theories of the earth's origins and history.
c) Petroleum geologists use fossils as correlation devices or predictors of depositional environment in their search for oil and gas.
d) Economic geologists use fossils as a guide in their search for mineral deposits in sedimentary rocks.
e) The geological time scale based on the fossil record has provided a framework for dividing up the geological past.
f) Fossils contribute important evidence to the study of evolution.

4. Societal Implications

a) Research continues to reconstruct the past history of the earth.
b) Fossil fuels represent an important and a non-renewable source of energy for today's society.
c) The vast number of petroleum and coal by-products contribute to our high standard of living.
d) The restructuring of past environments by scientists will indicate periods of climatic change, which may be useful in the projection of future climatic trends.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) laboratory or field work;
b) identification of some common fossils.

6. Safety Considerations

a) Students should be cautioned on the proper use of dilute hydrochloric acid and other chemicals.
b) Students should be cautioned to exercise care on field trips (e.g., to be aware of traffic at road cuts and falling rocks at cliff faces).
c) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) examine strata in the field or in a diagram and chart the depositional changes that took place in these strata, from the youngest to the oldest;
b) examine different types of unconformities and their meanings;
c) research the theories on the origins of life;
d) study a "living fossil", such as the shark or the coelacanth;
e) study the unusual way in which soft-bodied creatures, such as the woolly mammoth, have been preserved;
f) investigate the special ways in which the Roman towns of Pompeii and Herculaneum were preserved;
g) examine one major fossil-bearing area or zone in detail;
h) examine additional fossils, such as graptolite and ostracod;
i) examine microfossils;
j) study the development and preservation of vertebrates or dinosaurs;
k) investigate the human fossil record;
l) discuss the theories of mass extinction;
m) trace the fossil evidence of one organism (e.g., the horse);
n) using fossil evidence, describe life in detail during the Precambrian, Paleozoic, Mesozoic, and Cenozoic eras.

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*See the subsection entitled "Student Activities" on page 5.

8. Some Teaching Suggestions

a) Large hand specimens of rocks representing different environmental information are helpful for dealing with the rock record. These can be collected over a number of years.
b) Indications as to how the rates of sedimentation can vary geographically and over time should be discussed. A comparison should be made of the rates of sedimentation with the rate of tree-ring production, and the record of varve clays should be indicated (2c).
c) Slides or photographs of rock cuts are helpful to illustrate various environmental features.
d) Methods of preservation can be demonstrated through the use of plaster of Paris (2a).
e) Specimens should be kept in the laboratory to illustrate different types of preservation.
f) Laboratory exercises should be structured to enable students to draw and describe fossils while actually examining the specimens (2a).
g) Brachiopods, trilobites, coral, gastropods, pelecypods, cephalopods, crinoids, and bryozoa are the eight fossils most commonly found in North America. If there is a common local fossil, it should be included in the collection. A maximum of ten fossils should be examined (2a).
h) Fossil collecting at a local road cut or quarry (if possible) is extremely popular and is a good means of helping students identify the variety of fossil forms (6b).
i) It is important for students to practise extracting fossils from rocks and cleaning them (2a).
j) Films on fossil collecting should be obtained to assist in this unit (2d).
k) A visit to a museum that has a paleontology display is useful. Museums contain a quality of fossils that cannot be provided in a school setting (2d).
l) The usefulness and limitations of relative and chronometric dating should be stressed (2d).

Core Unit 5

The Dynamic Earth

Time: 15 hours

The purpose of this unit is to illustrate how the configuration of the planet's surface and surface expressions of internal earth forces such as earthquakes can be explained by the plate tectonics theory, which was introduced in unit 1. Students should also be aware that geologists are interested in studying deformations caused by earth movements and that the geological character of these deformations can be ascertained through the study of pre-existing features (e.g., bedding) in the field. The geological map is, therefore, an important mode for expressing such field data.

A minimum of two topics of five hours each are to be selected from the following:

- Plate tectonics
- Seismology
- Geological structures and geological mapping

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a curiosity about the natural forces that cause earthquakes (8a);
b) a confidence from and satisfaction in using the skills necessary for analysing geological data (3a, 3f);
c) an appreciation of the hazards of living in a tectonically active area (4a, 4b, 4d, 4e);
d) an appreciation of the variety of geological information that is presented on a geological map (4e).

Skills. Students will have the opportunity to develop skill in:

a) gathering, correlating, and interpreting geological data from a variety of sources (2b, 2c, 2f);
b) making inferences about the earth's interior, based on seismic data (2d);
c) determining the location of the epicentres and focus of individual earthquakes (2c);
d) identifying the problems associated with the prediction of earthquakes (2e);
e) distinguishing between observation and inference (2h);
f) measuring and plotting the attitude (dip and strike) of a rock bed (2g);
g) constructing hypotheses based on geological maps and sections (2k);
h) making inferences from geological maps and geological profiles (2k, 2l);
i) measuring and plotting pace and compass traverses (2e);
j) visualizing three-dimensional geological structures from two-dimensional map views (2i).

Knowledge. Students will be expected to:

a) define and use the following geological terms: elastic-rebound theory, continental and oceanic crusts, asthenosphere, subduction zone, continental margin, mid-ocean ridge, magnetic anomaly, lithospheric plate, diverging plate boundary, converging plate boundary, focus, epicentre, seismogram, seismograph, seiche, tsunami, liquefaction, magnitude, intensity, P-wave, S-wave, isoseismal line, geological map, geological structure, outcrop, contact, dip, strike, anticline, syncline, fold axis, symmetrical fold, asymmetrical fold, normal fault, reverse fault, strike-slip fault, oblique fault, fault plane, geological map (2a);
b) determine the relationship between earthquakes and crustal-plate boundaries;
c) name the major crustal plates and indicate the directions of their movement (2c);
d) describe and explain the assembly and subsequent break-up of Pangaea (4c, 8a);
e) explain the relationship between the major earth structures and crustal-plate boundaries (2c);
f) list and describe the Wegnerian and the major modern-day proofs for the plate tectonic theory (2a, 8a);
g) identify on a prepared diagram the ocean-floor features associated with mid-ocean ridges (2b);
h) list the effects an earthquake may have on urban areas, land, ocean, ground water, and surface waters (2e);
i) identify on a seismogram the arrival time of seismic waves and consequently determine the epicentral location of an earthquake (2d);
j) state the rules for locating the youngest layer in a simply layered sedimentary structure (2g);
k) determine the dip and strike of layers in tilted, folded, and faulted structures (2j);
l) explain the factors that determine the amount of bedrock exposed on an outcrop (2g);
m) identify the youngest formation from the legend shown on a geological map (2h);
n) label the elements of a fold and a fault (2g);
o) draw accurate geological profiles, using sample geological maps (2k);
p) correlate stratigraphic columns (2).

2. Student Activities

Students are to:

*a) cut out maps of the continents that border the Atlantic Ocean and arrange them into their predrift positions;
b) construct a profile of the Atlantic Ocean floor by plotting depth and distance data (8a);
*c) plot epicentre locations on a world map and superimpose plate boundaries (3a, 4a);
*d) calculate and locate earthquake epicentres on the basis of P-wave and S-wave arrival times (3b);
e) observe and note the courses and effects of earthquakes from an array of audio-visual materials (e.g., slides, films) (4a, 4b);
f) construct an isoseismal map of a region, using intensity and magnitude ratings (3c);
*g) use three-dimensional structural models to draw geological map views of simple structures, such as horizontal, tilted, folded, and faulted layers (8a);
h) draw geological maps of simple structures by transposing contacts from prepared three-dimensional diagrams (8a);
*i) construct a three-dimensional cut-out structural model;
j) note the meaning of *strike* and *dip* by examining three-dimensional block models (8b);
*k) draw geological profiles from map views;
l) draw a geological map based on data derived from simulated outcrops placed on the school playing field (8c).

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*See the subsection entitled "Student Activities" on page 5.

3. Applications

a) Mineral deposits can sometimes be related to plate boundaries.
b) The exploration for oil and natural gas relies on seismic methods, the interpretations of which are based on a knowledge of the manner in which body waves penetrate rocks of the earth's crust.
c) A network of seismic stations can be used to determine seismic sea-wave effects on coastal areas, and warnings of the waves can then be issued.
d) Microseismic events can be used to predict volcanic eruptions and earthquakes.
e) Geological maps and sections are used to locate favourable sites for construction, resource exploration, and development.
f) Geological sections are used in the mining industry to plan the safe and efficient development of an ore body.

4. Societal Implications

a) It is questionable whether urban communities should be developed in areas that are subject to severe earthquakes.
b) Research is required if we are to establish building codes and methods that will minimize damage to buildings and loss of life in the event of an earthquake.
c) Dr. Tuzo Wilson, a Canadian scientist, has contributed greatly to our understanding of plate tectonics.
d) Geological maps benefit urban development by helping identify suitable sites for waste disposal and buildings.
e) Geological maps identify hazardous areas such as fault zones so that building construction can be designed to accommodate such features.
f) Stratigraphic sections are used to help locate ground-water, oil, and natural-gas concentrations.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) assembling of data in cartographic form;
b) accurate interpretation of seismic data;
c) practical laboratory work and reports;
d) skill in drawing geological plan maps and cross sections;
e) skill in measuring strike and dip;
f) proper interpretations of geological structures from geological maps and three-dimensional models.

6. Safety Considerations

a) Students should be cautioned about the proper handling of laboratory equipment.
b) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) discuss how the theory of plate tectonics helps in the search for mineral deposits;
b) examine the relationship between the plotting of polar wanderings through geological time and the theory of continental drift (e.g., in relation to the continents that border the Atlantic Ocean);
c) discuss the contributions to the field of geology by earth scientists such as T. Wilson;
d) research the locations, frequency, and magnitudes of earthquakes in Canada;
e) keep a scrapbook of newspaper clippings on tectonically related phenomena and plot their locations on a world map of plates and plate boundaries;
f) draw isopachous maps of subsurface geological structures;
g) gather specific ore-body information on a mine in Ontario and construct a model geological profile of the mine;
h) gather information on the life of James Hutton;
i) draw their own geological maps and cross sections and describe the geological events that resulted in the structures on their maps.

8. Some Teaching Suggestions

a) This unit covers a broad field of geological ideas, which have been selected to demonstrate the mobile and changing nature of the planet. Teachers should devise techniques that present the plate tectonics theory and geological mapping in concrete form (e.g., by using visual media and models).
b) Students should understand that the reading and interpretation of simple geological maps are based on a solid understanding of maps and of structural rules.
c) An excellent way to apply a student's understanding of structures and maps is to conduct field investigations of simulated outcrops located on the playing field.

Core Unit 6

Case Studies in Geology

Time: 15 hours

The first five units of this course dealt with the components that make up geology. Unit 6 utilizes these components to study the geology of a region on the earth's surface.

Each region has some special geological significance. All are important and involve the study of more than one geological component. The case studies listed below are derived from both the Ontario geological record and records found in other parts of the world.

Students are to complete five case studies of three hours each from the following topics. A minimum of one case study should be selected from each grouping:

▸ A glacial study
  a) The Great Lakes of North America
  b) Niagara Falls and Niagara Gorge
  c) The local glacial record

▸ A study in volcanism
  a) Mount Saint Helens and the Cascades (or another strato-composite cone, such as Vesuvius)
  b) Kilauea and the Hawaiian Island chain (or another shield-cone area, such as Iceland)
  c) Geysers and hot springs of Yellowstone National Park, Wyoming (or another geyser and hot-spring area, such as those in New Zealand or Iceland)

▸ A study of exposed sedimentary rocks
  a) The Grand Canyon (or other canyon lands)
  b) The Petrified Forest of Arizona and the Painted Desert
  c) The badlands of Alberta (or South Dakota)
  d) Geology of a cave (e.g., Bonnechere, Mammoth, Carlsbad)
  e) The Michigan and southwestern Ontario (or another *cratonic*) basin
  f) A local Paleozoic record in Ontario

▸ A study of ancient rocks
  a) The Sudbury basin
  b) Extraterrestrial geology
  c) A local record in the Canadian Shield

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the work done by moving ice and running water during the last glacial epoch (3a);
b) an awareness of the different kinds of volcanic eruptions and a specific interest in at least one type (4b);
c) a respect for the power of the earth to produce events that cannot be controlled by humans (8d);
d) an awareness of the different types of erosion at work on the earth's surface;
e) an appreciation of the vast breadth of geological time;
f) an appreciation for the records of geological time that are stored in stratified rocks (4a);
g) an appreciation of special geological environments that are documented in the rocks (8b).

Skills. Students will have the opportunity to develop skill in:

a) researching specific topics in geology (2a, 2b);
b) communicating geological information.

Knowledge. Students will be expected to:

a) define and explain the following: continental glaciation, till, moraine, postglacial lake, cap-rock waterfall, gorge;
b) describe how glacial erosion and deposition have affected the area of study;
c) define and explain the following: composite (strato) volcano, cinder cone, shield volcano, basalt, andesite, tephra, geyser, hot springs (8a);
d) recognize the characteristics of one or more types of volcanic eruptions;
e) define and explain the following: erosion, uplift, stratified rocks, bed, formation (8e);
f) explain how the sedimentary record has been established in each case study;
g) explain what erosional processes have exposed the geological record (8c);
h) define and explain the following: fall-back breccia, orogeny;
i) describe how ancient geological records were accumulated (2a, 2b).

2. Student Activities

Students are to:

*a) present or debate issues arising from the case studies (4a-4c);
*b) analyse maps and diagrams illustrating some of the case studies in this unit.

3. Applications

a) Sand and gravel deposited from glaciation provide good raw materials for the aggregate industry.
b) In some places the rocks contain minerals that are of sufficient value to be mined.
c) In Iceland geysers and hot-spring areas are harnessed for hot-water and geothermal power.

4. Societal Implications

a) Many spectacular geological sites have become tourist attractions.
b) Volcanic areas tend to have good soils and to provide food for a large population.
c) Many of these sites provide full-time and seasonal employment in their local areas.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students' written and oral reports on the case studies.

6. Safety Considerations

The safety precautions necessary for this unit are those normally exercised in the classroom or in field situations. For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) build a scale model of a large terrestrial volcano such as Mauna Loa;
b) build a working model of a geyser;
c) construct a scale model of various geological features out of common materials.

8. Some Teaching Suggestions

a) Liberal use should be made in this unit of maps, diagrams, photographs, slides, and films.
b) This unit provides an excellent opportunity for students to engage in independent study on a topic of particular interest that is approved, monitored, and evaluated by the teacher.
c) There are many publications on the geology of the provincial, state, and national parks of Canada and the United States.
d) The Ontario Geological Survey is a good source of information on the Canadian Shield of Ontario.
e) Both the Geological Survey of Canada (GSC) and the United States Geological Survey (USGS) are sources of many publications and maps.
f) Astronomy magazines are good sources of information on extraterrestrial geology.

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*See the subsection entitled "Student Activities" on page 5.

Core Unit 7

Economic Geology

Time: 15 hours

Economic geology deals with the materials that humans take from the earth for the necessities of life and for comfort. The purpose of this unit is to study economic resources extracted from the earth.

This unit may be divided into topics such as the following:

- Exploring and developing minerals – open-pit and strip mining and the processing of minerals
- Underground mining and mineral processing
- Uses for minerals
- Quarrying and the aggregate industry
- Oil and gas development and exploration
- Ground-water exploration and development

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of fossil fuel as a non-renewable natural resource (4a, 4e);
b) a respect for the importance of minerals to our modern industrial society (3d);
c) an appreciation of the uneven distribution of mineral wealth throughout the world (4b, 4e);
d) a concern for the accelerating rate at which our non-renewable resources are being used up (4e);
e) a commitment to the conservation of all natural resources (4a);
f) an interest in the exploration for minerals (8d, 8f);
g) an appreciation of the difficulty and complexity of mineral discovery (4d);
h) an appreciation of the technological changes taking place in mineral exploration today (4d);
i) an appreciation of the complexity of the decision as to which mining method should be used in various applications (4e);
j) a concern for the demands being placed on the Canadian and world supply of crude oil and natural gas.

Skills. Students will have the opportunity to develop skill in:

a) analysing data with respect to non-renewable resources and the distribution of such resources;
b) explaining some of the instruments and techniques used in exploration (2c, 3b);
c) drawing sketches of the instruments and techniques used in exploration (3a);
d) drawing a design for a proposed mining operation to suit an ore body;
e) identifying common ore and industrial minerals (2d);
f) identifying the minerals that are used in various finished products (3d);
g) determining the best place to drill in a prospective oil find;
h) determining the location for aggregate collection and development (3e);
i) sketching the water cycle, the water table, artesian wells, and the structures associated with the geological work of ground water (4f).

Knowledge. Students will be expected to:

a) define the following terms:
    - non-renewable resource, ore mineral, fossil fuel, ground water;
    - radioactivity, magnetism, gravity, anomaly, diamond drilling, assaying;
    - mine, mill, smelter, refinery;
    - ore mineral, industrial mineral, precious mineral;
    - rig, oil well, drill bit, mud, Christmas tree, wildcat well;
    - aggregate, quarry, limestone, crushed stone, building stone;
    - hydrologic cycle, aquifer, permeability, porosity, percolation, saturation, aeration, water table (2a-2g);

b) recognize the discrepancy in mineral wealth throughout the world (4b);
c) locate major mineral deposits on a map of Canada (2a);
d) locate Ontario's most important mining regions (2b);
e) distinguish between the role of a prospector and that of a geologist (4d);
f) differentiate between geophysical and geochemical prospecting (8a);
g) describe the roles of magnetometers, gravimeters, seismographs, and geiger counters in mineral exploration (2c, 3a);
h) outline the types of geological information that are furnished by satellite;
i) describe the procedures for staking a claim (8c);

j) identify the importance of assaying to the decision to exploit minerals (3c);
k) distinguish between open-pit and underground mining (8d);
l) compare strip mining for coal and open-pit mining for other minerals;
m) explain why the structure of an open-pit mine must be carefully designed;
n) identify the following features of an underground mine: headframe, hoist room, cage, shaft, adit, haulageway, stope (8c);
o) analyse the advantages and disadvantages of one or more underground mining methods (8b, 8d);
p) differentiate between a rock-forming mineral and an economic mineral (8e);
q) identify some common ore minerals and relate these to their extracted metal (e.g., chalcopyrite – copper; galena – lead; sphalerite – zinc; nickeliferous pyrrhotite – nickel; hematite, magnetite, limonite – iron) (2d);
r) identify and state the uses for some common industrial minerals (e.g., halite – salt; sylvite (potash) – fertilizer; garnet – abrasives; serpentine – asbestos; calcite – cement; clay minerals – bricks) (2e);
s) differentiate among gems, semiprecious stones, and ornamental stones (2e);
t) identify the importance of being within the market area to the quarrying of stone (3e);
u) gain some understanding of what it is like to work on an oil rig;
v) explain the role of ground water as a storage reservoir (2f, 3f);
w) describe how the properties of ground water are determined by the physical properties of rocks (2g);
x) state the factors that govern the recharge of ground water (2f);
y) state the effects of the withdrawal of water from an aquifer (4f).

2. Student Activities

Students are to:

*a) locate on a map of Canada the main mineral occurrences (4a);
*b) locate on a map of Ontario the most important mining regions (4c);
c) make measurements with such exploration instruments as a magnetometer and a geiger counter, if such instruments are available (3a);
*d) identify important ore and industrial minerals (8e);
*e) make a chart of minerals and their uses (8c);
*f) sketch, and explain the role of ground water as part of, the hydrologic cycle (3f, 4f);
g) analyse the various types of rocks to determine their porosity (3f, 8h).

3. Applications

a) Magnetic gravity and electrical methods of conducting a geophysical survey are widely used in the exploration for minerals.
b) Seismic survey is widely used in the exploration for oil.
c) A calculation of the per cent of metal in metallic ores (assaying) helps determine whether a mineral deposit can be mined economically.
d) The existence and exploitation of large mineral deposits mean employment for Ontarians and revenue for the province.
e) The existence of a nearby aggregate supply provides a community with construction materials.
f) The existence of large ground-water supplies creates a successful farming environment in areas with little precipitation.

4. Societal Implications

a) Canada possesses abundant natural resources, which have allowed Canadians to achieve a high standard of living. These resources have played a major role in creating the nation's wealth.
b) Industrial societies, with their dependence on resources, will place increasing demands on an integrated system of resource exploration.
c) Ontario has a broad range of ore minerals and industrial minerals, from which many materials are extracted.
d) Since industry is very dependent on various rock resources, it is essential that exploration in the field and research in the laboratory continue.
e) A reliable and plentiful supply of oil and natural gas provides great political and economic power for any jurisdiction.
f) Ground water is a significant factor in controlling the distribution of vegetation, thereby influencing desertification and erosion.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students' written or oral work.

6. Safety Considerations

a) Students should exercise care if a field trip is undertaken.
b) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

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*See the subsection entitled "Student Activities" on page 5.

7. Possible Extensions

Some students might:

a) analyse the role of politics in resource development and implementation, both nationally and internationally;
b) extend their knowledge of geophysical exploration methods;
c) study the life and accomplishments of a noted Canadian geophysicist;
d) study or visit a specific open-pit mining operation (6a);
e) study or visit a specific underground mining operation (6a);
f) study or visit a plant that processes minerals (6a);
g) make a study of precious minerals;
h) study or visit an aggregate plant in the local area;
i) visit a water-treatment plant to observe the purification of water under conditions similar to those underground;
j) visit a town having a ground-water supply system to observe the techniques used to obtain the water.

8. Some Teaching Suggestions

a) The use of case histories to illustrate different exploration methods should be encouraged (3d).
b) The Ontario Geological Survey is a good source of information on exploration (2c).
c) The Ontario Mining Association is a good source of material on mining (2e).
d) There are several good films on mining methods.
e) The collecting of a master set of ore minerals will be advantageous (2d).
f) The collecting of old mining materials, such as drill cores and old drill bits, will enhance the learning in this unit.
g) There are several good films on exploration and drilling for oil (2c).
h) Transparent dishes containing water coloured by ink can be used to illustrate the movement of water through sand (2g).

Core Unit 8

Environmental Geology

Time: 10 hours

Most geological changes occur at a pace so slow that their effects cannot be measured in the span of a human life. Some changes are measurable, such as those that involve such natural catastrophes as earthquakes and volcanic eruptions. In the past century, human activity has also become a major agent of measurable geological change. The extraction and processing of raw materials have altered and greatly accelerated the pace of many geological processes. Environmental geology allows us to assess these changes and to determine how they may hinder the present and future growth and development of our society.

A minimum of two studies of five hours each are to be selected from the following list:

- Mine-site requirements and concerns
- Harmful waste disposal
- The reclamation of tailings dumps
- Living in tectonically active areas
- Drainage basins and shoreline hazards

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an awareness that our knowledge of the earth should be applied to our activities, both in the present and in the future (3a);
b) a respect for the natural environment (3b);
c) a concern for those environmental hazards that are predictable and that can be avoided (3c);
d) a commitment to the design of mine sites that minimize environmental impact (3b);
e) an awareness of the need to rehabilitate old quarry and mine sites (3e);

f) an awareness of the difficulty of choosing toxic-waste sites (3c);
g) an appreciation of the benefits to the local community of reclaiming mine-tailings sites (3a, 8c);
h) a concern for housing and other human activities in zones of acute tectonic danger (3d);
i) an awareness that a drainage basin and shorelines are dynamic features and a commitment to the environmental enhancement and preservation of the local shoreline or watershed (3a).

Skills. Students will have the opportunity to develop skill in:

a) making decisions by analysing priorities and determining a balance between human demands and the need for conservation (8a);
b) role-playing the various concerned groups in a conflict involving the environment and human demands (3d).

Knowledge. Students will be expected to:

a) define the following terms: environmental impact, pollution, acidity, tailings, rehabilitation, reclamation, toxic rain, radioactivity (2a);
b) outline the problem presented by a mine that lacks proper environmental controls on the dumping of waste (2b);
c) state the possible actions needed to rehabilitate a quarry or an old mine site and recognize the advantages to humans of such rehabilitation;
d) explain how improper waste disposal can affect hydrologic conditions and contaminate ground water (3e, 8e);
e) outline the steps necessary to reclaim a former mine-tailings dump (8d);
f) explain the role of various types of pollutants in modifying the environment;
g) define the terms *earthquake* and *flood*;
h) differentiate among slides, flows, and solifluction;
i) explain the relationship of earthquakes and volcanoes to natural disasters (2e);
j) describe what is necessary to predict earthquakes and volcanic eruptions and outline what must be done to prepare for such events;
k) define and explain the following terms: watershed, flood, storm waves (2d);
l) describe the steps necessary for protection against flood and wave damage;
m) explain how urban land use can often be dictated by the natural environment.

2. Student Activities

Students are to:

*a) establish a rehabilitation program compatible with the surrounding land use for an abandoned pit or quarry (3a);
*b) study the effects on the surrounding vegetation when the waters from a dump site seep into the surrounding drainage system (3b);
c) study the effects on the hydrologic cycle of burning coal and smelting sulphide ores (3c);
*d) determine through analysis the impact of a catastrophic event on the environment (3d);
e) survey the human awareness of and response to possible environmental catastrophes (3b).

3. Applications

a) A knowledge of environmental geology is useful in making both short-term and long-term decisions pertaining to the environment.
b) A knowledge of potential environmental damage is valuable in planning and implementing new mining sites.
c) A knowledge of toxic wastes will help us understand the current debate over dump sites.
d) Natural hazards could be minimized through the avoidance of high-risk areas in future development.
e) A knowledge of environmental geology is useful in understanding the restraints placed on the exploitation of the earth.

4. Societal Implications

a) The earth is a small planet with a fragile environment.
b) Scientists must continually monitor all human and natural geological activity on the earth.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students' written and oral reports on the topics selected for discussion.

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*See the subsection entitled "Student Activities" on page 5.

6. Safety Considerations

The safety precautions necessary for this unit are those normally exercised in the classroom or in field situations. For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) participate in a local field trip designed with an emphasis on environmental geology;
b) note the legal requirements for new mining operations that could have an environmental impact;
c) note the requirements in the laws of various jurisdictions regarding the clean-up and rehabilitation of former mine or quarry sites;
d) visit a reclaimed or abandoned quarry or pit and write a report on their observations;
e) test or observe the effects of acid rain or of the acidic leaching of old mining sites;
f) report on the dangers caused by nuclear waste.

8. Some Teaching Suggestions

a) This unit lends itself to group work and class discussion.
b) Case studies should be utilized where possible.
c) The Ontario Geological Survey and the Ministry of the Environment can provide information on the rehabilitation of former mine or quarry sites.
d) Many large mines will supply information on their steps to rehabilitate areas.
e) Students might prepare a scrapbook of environmental geology articles over a period of time from the local and regional newspapers.
f) A number of films are available on this subject.

Geology, Grade 12, Advanced Level
(GGE4A/SGE4A)

Core Units

Planet Earth
Minerals
The Earth's Crust: Rocks
The Dynamic Earth
The Record of Life
Clocks for the Rocks
Geological Maps and Illustrations
Environmental Geology
The Ontario Record

(92 hours)

Optional Units

The Precambrian Shield
Paleozoic Rocks
Glacial Terrain
The Great Lakes
Drainage Basins
Ground Water
Geophysical and Geochemical Exploration
Extraterrestrial Geology
Locally Designed Unit

(18 hours)

Core Unit 1

Planet Earth

Time: 3 hours

Planet Earth is a finite world, limited both in its size and in its resources. It is also a dynamic planet, changing slowly over time. The purpose of this unit is to introduce students to the limited space and resources available to humankind, the dynamic nature of the earth, and some of the planet's physical characteristics.

This unit may be divided into topics such as the following:

- The nature of geology
- A review of terminology and elementary concepts
- The physical shape of the earth
- Continent-ocean distribution
- The interior of the earth

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the importance of geology to society;
b) an appreciation of the physical size and limitations of the earth (2a, 2b);
c) an appreciation of the structure of the earth (2b);
d) a curiosity about the dynamic quality of the earth and its implications for humankind (2c);
e) an open-minded and questioning attitude towards research about the earth (2e, 2f).

Skills. Students will have the opportunity to develop skill in:

a) identifying the earth as a somewhat imperfect sphere (2a, 6a);
b) graphing selected data (2b);
c) developing a model to indicate the internal structure of the earth (2d);
d) measuring the size of the earth by means of a historical method (2a);
e) making inferences about geological events that resulted from internal earth processes (2c, 2d).

Knowledge. Students will be expected to:

a) explain the following terms: oblate spheroid, continent, ocean, continental shelf, continental slope, deep-sea basin, lithosphere, asthenosphere, geothermal gradient, graphic curve, discontinuity, isostasy, direct observation, indirect observation, earthquake, atmosphere, hydrosphere;
b) differentiate between oceanic and continental crust (2b);
c) differentiate between the older term *crust* and the newer term *lithosphere* (2b, 2c);
d) name and briefly outline the characteristics of the various zones composing the earth's structure (2c, 2d);
e) describe the nature of geology and the role of the geologist in today's world (2e, 2f).

2. Student Activities

Students are to:

*a) explain the irregularities in the earth's shape;
b) plot a graph to illustrate the distribution of land in relation to sea level;
c) participate in a discussion of the problems caused by the dynamic quality of the earth;
d) construct a diagram of the internal structure of the earth;
*e) participate in a discussion of the limitations of the earth and its resources;
f) participate in a discussion of the role of the geologist.

3. Applications

a) An introductory study of the earth helps in the identification of some of the phenomena that require explanation and further study.
b) Geology plays a key role in any scientific study of the earth.

4. Societal Implications

a) Society uses geological knowledge to explain natural phenomena.
b) A knowledge of potentially active zones can be used to prevent disasters.
c) Decisions in favour of development as opposed to conservation of the environment may have a significant geological impact.

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*See the subsection entitled "Student Activities" on page 5.

5. Evaluation of Student Achievement

At least 20 per cent of the term mark for this unit is to be based on students':

a) participation in class discussions;
b) neat and accurate diagrams or sketches.

6. Safety Considerations

a) Care must be taken if centrifugal hoop devices are used to illustrate the polar flattening of the earth.
b) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) investigate modern methods for determining the shape of the earth;
b) research the mathematical technique for determining the density of the earth;
c) research the contribution of Andrija Mohorovičić to the study of the earth.

8. Some Teaching Suggestions

a) A centrifugal hoop can be used to demonstrate the polar flattening of the earth.
b) The use of indirect observation and the role of geophysics in determining the nature of the earth's interior should be stressed. An explanation of earthquakes and earthquake waves is not intended in this unit.

Core Unit 2

Minerals

Time: 18 hours

Minerals are the foundation of geology, the building blocks of the earth, and the basis of our industrial society. They are important economically, scientifically, and aesthetically. Economically, minerals are a source of many of the things we enjoy today. Scientifically, minerals make up the data bank from which we learn about geological processes. Aesthetically, minerals enrich our lives as gems and as specimens in their natural surroundings, in collections, and in museum displays. In this unit students will learn the definition of *mineral* and something about the classification, identification, and formation of some of the common minerals.

This unit may be divided into topics such as the following:

- Definition of *mineral*
- Physical properties of minerals
- Chemical properties of minerals
- Classification of minerals
- Identification of minerals
- Formation of minerals

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a curiosity as to how minerals are formed;
b) an appreciation of the consistency of both the physical and the chemical properties of minerals;
c) an appreciation of the importance of minerals in our modern industrial society.

Skills. Students will have the opportunity to develop skill in:

a) determining the specific gravity of a mineral (2a, 2b, 8a);
b) determining the streak of a mineral (2a, 2b);
c) determining the hardness of a mineral (2a, 2b);
d) determining the cleavage or fracture of a mineral (2a, 2b, 8a);
e) determining the lustre of a mineral (2a, 2b);
f) determining a form of a mineral (2a, 2b);
g) determining a mineral's identity (2a, 2b);
h) determining the special properties of a mineral (2a, 2b);
i) classifying minerals into families (2b, 2c);
j) identifying at least twenty-five common minerals (2b).

Knowledge. Students will be expected to:

a) list the five most abundant elements in the earth (2a);
b) relate the abundant elements to the composition of the common minerals (2a);
c) explain the meaning of the following terms: mineral, rock, element, compound, crystalline structure, streak, cleavage, fracture, Moh's scale of hardness, specific gravity, magnetism, fluorescence, radioactivity, ore, native mineral;
d) describe the characteristics of different families of minerals (2a, 2b, 2e);
e) identify twenty-five minerals, using common physical and chemical tests (2a, 2b);
f) explain the origins of mineral ores (2d);
g) locate major mineral deposits on a map of Canada (2g).

2. Student Activities

Students are to:

*a) perform basic physical and chemical tests to illustrate some of the properties of different minerals (5a, 5c, 6a, 8c);
*b) identify minerals on the basis of experimental results (5a, 5c, 8c);
c) construct flow charts of the mineral families to illustrate their components;
*d) note the ways in which mineral ores originate;
*e) develop a working knowledge of the common minerals and their families;
f) grow crystals, using a solution of copper sulphate, nickel sulphate, or chrome alum;
*g) locate on a map of Canada the main locations of minerals.

3. Applications

a) A knowledge of the chemical composition of minerals enables the mining industry to develop means of removing metals from their ores.
b) A calculation of the per cent of metal in metal ores helps to determine whether a mineral deposit can be mined economically.
c) A knowledge of methods of mineral formation is helpful in field exploration.
d) A knowledge of the physical or chemical properties of minerals explains the uses of many minerals. For example, the three-dimensional network structure of diamond, garnet, and corundum (compared to the two-dimensional network structure of graphite) explains their use as abrasives.

4. Societal Implications

a) Canada possesses abundant natural resources. These resources have played a major role in creating the nation's wealth and allowing us to achieve a high standard of living.
b) Ontario has a broad range of ores, from which many materials are extracted.
c) Smelting and refining processes may result in the contamination of the environment (e.g., acid rain results from the processing of sulphide minerals).
d) The mining industry and related manufacturing industries have responsibilities in the area of health and safety.
e) Science and technology provide the means of converting Canada's mineral resources into useful products.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) performance of physical and chemical tests on minerals;
b) laboratory reports;
c) performance of a practical laboratory test on mineral identification.

6. Safety Considerations

a) Students should be instructed in the proper use of dilute hydrochloric acid for the carbonate test.
b) Students should be cautioned to rinse thoroughly all samples on which acid has been used.
c) Students must wear safety glasses when splitting minerals.
d) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

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*See the subsection entitled "Student Activities" on page 5.

7. Possible Extensions

Some students might:

a) investigate gemstones, considering the chemical and physical properties that make them unique and valuable;
b) research advanced mineral-identification techniques, such as atomic-absorption spectra, polarized light, and X-ray refraction;
c) research crystals and crystal classification;
d) investigate mining techniques or mining regions.

8. Some Teaching Suggestions

a) A series of laboratory exercises on testing techniques (e.g., for hardness, streak, lustre) in which students handle the mineral samples can be designed.
b) Students can organize selected minerals by family, physical properties, chemical properties, and diagnostic features. The following minerals and groupings may be used:

Rock-Forming Minerals	Non-Metallic Minerals	Metallic Minerals
silica minerals	sulphur	iron minerals
silicate minerals	graphite	copper
carbonate minerals	diamond	cinnebar
	chrysotile	pentlandite
	corundum	galena
	fluorite	sphalerite
	sylvite	cassiterite
		uraninite

c) Films or slides may be used to reinforce the idea of grouping minerals according to their physical and chemical properties.
d) A decision-making simulation exercise involving a hypothetical country that contains an exploitable mineral may be a useful activity. Scientific, technical, geological, social, environmental, and economic factors should be taken into account in the simulation.
e) Students could gather data about an area in Ontario in which specific minerals play an important role in the economy (e.g., the Sudbury basin, Hemlo, Timmins, Cobalt, Elliot Lake).
f) The pamphlet entitled *The Study of Minerals*, prepared by the Ontario Geological Survey, should be obtained from the Ministry of Northern Development and Mines.

Core Unit 3

The Earth's Crust: Rocks

Time: 16 hours

Petrology is the study of one of the earth's primary components, rocks. The history of the earth is written in the rocks. To read and understand this history, we must learn the language of geology. The rocks are the words; minerals are the alphabet. The purpose of this unit is to examine these rocks in all their variations of form, appearance, and composition.

This unit may be divided into topics such as the following:

- Review of rock-forming minerals
- Definition of a rock
- Classification of rocks
- Physical properties of rocks
- Chemical properties of rocks
- Identification of rocks
- Formation of rocks
- Rocks and soil formation

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation that rocks are one of the earth's primary components;
b) an appreciation of the significance of rocks as a primary source of materials in an industrial society;
c) a curiosity about rocks as a record of the past;
d) a curiosity about the combinations of minerals that make up various rocks;
e) an appreciation that metamorphism occurs as rocks adapt to suit new environments.

Skills. Students will have the opportunity to develop skill in:

a) relating their knowledge of rock-forming minerals to the rocks themselves (2b, 2e);
b) handling rock samples and equipment such as microscopes (2e, 6a, 6c);
c) drawing inferences from both quantitative and qualitative observations (2a, 2b, 2e, 2g);
d) developing charts from given or derived data (8g);
e) classifying rocks according to information derived from an analysis of their properties (2c, 2e, 2g);
f) interpreting graphs to further their understanding of rocks and their origins (2b, 2e, 2g);
g) performing experiments from which conclusions can be drawn to reinforce their understanding of the processes of rock formation (2a, 2c, 6a, 6b);
h) determining the economic value of rocks on the basis of their composition.

Knowledge. Students will be expected to:

a) explain the meaning of the following terms: petrology, classification, igneous (magma, lava, intrusive, plutonic, extrusive, tephra, texture, magmatic differentiation), sedimentary (lithification, cementation, clastic, stratification, bedding, sorting, evaporite), metamorphic (foliation, active, passive, dynamic, progressive regional metamorphism, contact), rock cycle;
b) relate rock types to the composition of the lithosphere (2a);
c) use the terms *igneous*, *sedimentary*, and *metamorphic* when classifying rocks;
d) explain how a rock's texture provides information about the physical environment in which the rock was formed (2c, 2e);
e) describe the identification of an igneous rock on the basis of mineral composition (2a);
f) distinguish between mechanical and chemical weathering as rock-forming agents (2f);
g) explain sedimentary environments in relation to the type of sedimentary rock formed (2g);
h) describe the formation of sedimentary rock, using the concepts of weathering, transportation, and deposition (2f, 2g);
i) briefly indicate how soils are derived from bedrock;
j) explain how crystallization in magma or lava leads to the formation of different types of igneous rocks (e.g., intrusive, extrusive) (2c, 2e);
k) describe the role of water, pressure, and temperature in the formation of metamorphic rocks (2g, 2h);
l) differentiate between contact and progressive regional metamorphism and between active and passive metamorphic rocks (2h);
m) identify rocks on the basis of their physical and chemical characteristics (2a-2h).

2. Student Activities

Students are to:

a) identify selected hand samples of rock and place them in appropriate groups (6b);
b) examine some of the selected hand samples to determine the identity of the identifying minerals present in each sample (6a, 6b);
*c) perform an experiment to illustrate the relationship of crystallinity to the rate of cooling of the selected rock melt (6b);
d) perform an experiment to determine the effect of acid on carbonate rocks (6a, 6b);
*e) examine selected igneous rocks to determine their mineral content (6a, 8b);
f) evaluate the relative importance of the different types of weathering under different climatic conditions;
g) analyse selected sedimentary rocks on the basis of their depositional environments;
h) analyse selected metamorphic rocks (8c, 8d).

3. Applications

a) A knowledge of rock types and structures developed through geological processes provides us with an insight into potential mineral deposits.
b) A knowledge of rocks provides us with an insight into the earth's history that is essential to solving geological problems.
c) A knowledge of rocks and their composition is important in choosing building materials and construction techniques.
d) An awareness of weathering processes, particularly in urban areas, can provide us with an insight into preventative measures.
e) Variations in rock type influence soil formation, fertility, and land use.

4. Societal Implications

a) Since industry is very dependent on various rock resources, it is essential that exploration in the field and research in the laboratory continue.
b) While controls on quarry and pit operations are necessary if we are to preserve the beauty of our landscape, aggregates are an essential part of the construction industry.
c) Sound geological considerations are essential for the safe storage of nuclear wastes.

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*See the subsection entitled "Student Activities" on page 5.

d) In the past the weathering of rocks has been an accepted natural process; however, the effects on rocks and building stone of increasing amounts of acid rain may be far-reaching.
e) Because a soil profile takes about a century to develop, soil conservation is essential.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) development and interpretation of graphs;
b) identification of rocks from samples provided;
c) practical laboratory work;
d) laboratory reports and contributions to group activities.

6. Safety Considerations

a) Students should again be cautioned on the proper use of diluted hydrochloric acid for the carbonate test.
b) Students should use protective eyewear when working with acid and chipping or fracturing rocks.
c) The proper use of a microscope should be reviewed.
d) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) research evidence of progressive regional metamorphism (e.g., the Frontenac Axis);
b) reconstruct the geological sequence of events in a region from which rock samples have been taken;
c) investigate the composition of a crushed rock or sand by determining the percentage mass and volume of each component;
d) determine soil texture through an interpretation of triangular diagrams;
e) observe the relationship between settling time and particle size through experimentation;
f) perform experiments to examine the two types of weathering, mechanical and chemical;
g) analyse the mineral content of selected rocks, using thin sections and a microscope;
h) research the various types of limestone;
i) investigate the possible metamorphic origin of granite.

8. Some Teaching Suggestions

a) It is essential that students have a thorough understanding of the rock-forming minerals before beginning this unit.
b) The task of studying igneous rocks may be simplified through the use of examples of equivalent combinations (e.g., gabbro and basalt).
c) Students can better understand the concept of progressive regional metamorphism (e.g., of shale or basalt) if the samples are displayed in order, from low-grade to high-grade metamorphism.
d) Students can be shown examples of contact metamorphism and active and passive metamorphism. They should be able to move beyond the traditional "limestone to marble" concept to the realization that metamorphism is the adaptation of the pre-existing rock to its new environment.
e) The laboratory work required in this unit, particularly that involving identification, lends itself strongly to team or group efforts.
f) A field trip to rock exposures or cemeteries will give students the opportunity to apply their identification skills at a practical level.
g) Students should organize and summarize their notes in chart form, showing the major family groupings (igneous, sedimentary, and metamorphic) and the many subgroups within each of the rock families. Students might study the following rocks:

Igneous Rocks	Sedimentary Rocks	Metamorphic Rocks
granite	sandstone	slate
syenite	conglomerate	phyllite
diorite	shale	schist
basalt	siltstone	gneiss
granodiorite	limestone	marble
gabbro	dolomite	quartzite
pegmatite	gypsum	tillite
dunite	halite	
porphyry	coal	

Core Unit 4

The Dynamic Earth

Time: 18 hours

To humans, the earth often appears static and unchanging. The purpose of this unit is to introduce students to the dynamic nature of the earth. They will have the opportunity to acquire an understanding of internal tectonic processes, their causes, and their surface manifestations under the unifying theory known as *plate tectonics*.

This unit may be divided into topics such as the following:

- The internal structure of the earth
- Seismology
- Plate tectonics
- Tectonic processes

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a curiosity about the natural forces that continue to change the earth (2a, 2c);
b) a questioning attitude towards the plate tectonics theory, which attempts to explain natural phenomena (2c, 2d);
c) an appreciation of the hazards of living in tectonically active zones of the earth (2e).

Skills. Students will have the opportunity to develop skill in:

a) gathering, correlating, and interpreting data from different sources (2a);
b) assembling data in cartographic form (2c);
c) making inferences about the earth's interior based on seismic data (2a);
d) drawing detailed, labelled diagrams to illustrate geological structures (2d);
e) classifying landforms according to their type and origin (2d);
f) analysing photographs to explain geological processes or structures (2c, 2d).

Knowledge. Students will be expected to:

a) explain the meaning of the following terms: (i) *seismology* – body waves, P-waves, S-waves, elastic rebound theory, energy, stress, surface waves, L-waves, isoseismic line, seismograph, tsunami, Richter scale, liquefication; (ii) *plate tectonics* – continental crust, oceanic crust, mid-ocean ridge, trench, transform fault, asthenosphere, convection current, plume, hot spot, paleomagnetism, paleoglaciation, Pangaea, Sea of Tethys, Laurasia, Gondwanaland; (iii) *tectonics* – fold, geosyncline, anticline, syncline, limb, open fold, closed fold, fault, joint, hanging wall, footwall, normal fault, reverse fault, thrust fault, strike, dip; (iv) *volcanism* – intrusive, batholith, laccolith, dike, sill, magma, lava, tephra, extrusive, crater, caldera, shield cone, composite cone, cinder cone, lava plateau, hot spring, geyser, ring of fire;
b) analyse a seismograph recording, identifying foreshocks, P-waves, S-waves, L-waves, and aftershocks (2a, 2b);
c) describe earthquake waves and explain how they are used to analyse the interior of the earth (2a);
d) describe and explain current methods of determining the magnitude of an earthquake (2e);
e) describe current methods of predicting the occurrence of earthquakes (2e);
f) analyse the world pattern of earthquakes and earthquake foci (2c);
g) determine the relationship between earthquakes and plate boundaries (2c);
h) name major crustal plates and indicate directions of movement (2c);
i) describe and explain the assembly and subsequent break-up of Pangaea;
j) indicate the evidence for the theory of plate tectonics;
k) recognize the directions from which forces are applied to produce tectonic belts in the earth's crust (2d);
l) draw and label the elements of faults and folds, including geosynclines;
m) explain the relationship between volcanism and plate boundaries (2d);
n) differentiate between intrusive and extrusive volcanism (2d);
o) describe and explain the different types of volcanic eruptions (2d).

2. Student Activities

Students are to:

*a) examine models or diagrams of the earth in cross section and, using travel-time curves, explain the internal structure of the earth (5b);
b) plot the location of an earthquake epicentre, given the necessary data (5a);
*c) construct maps and diagrams to illustrate the interrelationships among plate motion, plate boundaries, earthquakes, and tectonic processes (8a, 8b);
*d) draw and label diagrams to explain the geometry and nomenclature of folds, faults, and volcanic structures (5d);
e) participate in a class discussion of the costs and benefits to society of sudden tectonic events, such as earthquakes and volcanic eruptions.

3. Applications

a) Those who explore for oil and gas use seismic methods, the interpretations of which are based on a knowledge of the manner in which body waves penetrate rocks in the earth's crust.
b) Seismic stations can be used to detect underground nuclear explosions.
c) Mineral deposits can sometimes be correlated to plate boundaries.
d) The geothermal energy associated with volcanism can sometimes be harnessed to heat buildings and generate electricity.
e) Microseismic events can be used to predict volcanic eruptions and earthquakes.

4. Societal Implications

a) Scientifically based statements are useful in explaining such natural events as earthquakes and volcanoes.
b) It is questionable whether urban communities should be developed in areas that are subject to severe earthquakes or volcanic eruptions.
c) Research is required if we are to establish building codes and methods that will minimize damage to buildings and loss of life in the event of an earthquake.
d) Earthquakes and volcanoes have often changed the course of history within a country.
e) Research will continue to improve our understanding of the dynamic earth. In the future it may be possible to improve greatly the quality of life in tectonically active zones.

5. Evaluation of Student Achievement

At least 30 per cent of the term mark for this unit is to be based on students':

a) assembly of data in cartographic form;
b) accurate interpretations of seismic data;
c) practical laboratory work and reports;
d) drawings and explanations of tectonic structures.

6. Safety Considerations

a) Students should be instructed in the proper handling of laboratory equipment.
b) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) investigate the Mercalli and Modified Richter scales in detail;
b) construct a series of map overlays, using onionskin paper, to show the relationships among plate boundaries, plate motion, earthquake focus, fold mountain belts, and volcanisms;
c) examine the relationship between polar wandering curves and sea-floor spreading;
d) discuss the contributions of such earth scientists as Wegener, Holmes, Hess, Dietz, Vine, and Wilson;
e) investigate the growth of continents;
f) investigate plate boundaries in depth, for example, consider the types of subduction (e.g., continent-continent, continent-ocean);
g) investigate several famous volcanic eruptions (e.g., Krakatoa, Vesuvius);
h) construct an isoseismal map of a hypothetical earthquake, including the location of the epicentre, based on time-travel data;
i) do a library search to determine where and how frequently earthquakes occur in Canada and identify the location and the magnitude of the largest Canadian earthquakes;
j) collect newspaper clippings on tectonically related phenomena, relating them to plates and plate boundaries;
k) research evidence for pre-Pangaea drift.

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*See the subsection entitled "Student Activities" on page 5.

8. Some Teaching Suggestions

a) This unit covers a broad field in order to demonstrate the dynamic nature of the earth. The topics should be taught under the unifying theory of plate tectonics and should focus on the earth as a whole.
b) The nature of a theory should be stressed. Students should realize that the vast majority of earth scientists accept the theory of plate tectonics.
c) It is not expected that all of the topics in this unit will be covered in the same depth. Since plate tectonics is central to the theme of this unit, it should be treated in more detail than other topics.
d) A "dynamic earth" implies a changing earth. For this reason, geological time should be introduced in a general way during the study of the structures in the earth's crust.
e) Reference materials are readily available. Care should be taken that the materials are current and that the student is not overwhelmed by such materials.
f) By cutting a newspaper page into geometric shapes and reconstructing it, students can create an excellent analogy to the assembly of Pangaea.

Core Unit 5

The Record of Life

Time: 14 hours

The Geologic Time Scale is a record of the history of the earth itself. It is based on the study of fossils and the principles of stratigraphy. The time scale has withstood critical examination, changing slightly as paleontologists have unearthed and considered new evidence. It reveals an earth that is believed to have undergone slow physical changes while supporting life of increasing complexity. This scientific perspective is included within the theory of evolution. The purpose of this unit is to allow students to view the earth over the enormity of geological time from a scientific viewpoint.

This unit may be divided into topics such as the following:

- The Geologic Time Scale
- Fossils and fossilization
- Theories of the origin and development of the earth and of life on the earth

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a questioning attitude towards the Geologic Time Scale, which, like other scientific models, is tentative and has changed somewhat since it was first introduced;
b) an appreciation of the role of paleontology in the science of geology (2a);
c) an appreciation of the role of fossils as tools for biostratigraphic correlation and indicators of depositional environments and the importance of these indicators to the petroleum industry and to other areas of the economy;
d) an appreciation of the bias of the fossil record;
e) an appreciation of the relatively short period of time that people have been on the earth.

Skills. Students will have the opportunity to develop skill in:

a) carrying out laboratory and, location permitting, field-study techniques, including the sketching, identification, and classification of fossils (2c, 6b);
b) using and interpreting the Geologic Time Scale;
c) assembling data and plotting a linear graph of the Geologic Time Scale (2d);
d) interpreting experimental data and formulating a graph on radioactive decay (2a, 2c);
e) identifying some significant forms of life over geological history;
f) making inferences about the age of landforms based on their appearance as a result of erosional processes;
g) analysing geological sections and identifying their time sequence and unconformities;
h) evaluating early attempts at time calibrations, for example, the use of rates of erosion and transport.

Knowledge. Students will be expected to:

a) explain the meaning of the following terms: eon, era, period, epoch, uniformitarianism, superposition, unconformity, radioactive decay, Ediacaran fossils, index fossils, ectothermy, endothermy;
b) describe the processes by which organisms were preserved in rocks;
c) distinguish among eons, eras, periods, and epochs;
d) differentiate between relative and absolute dating;
e) describe the diversity of life in the Proterozoic era and the ranges of important groups of fossils that date from it;
f) describe the diversity of life in the Paleozoic era and the ranges of important groups of fossils that date from it;
g) describe the diversity of life in the Mesozoic era and the ranges of important groups of fossils that date from it;
h) describe the diversity of life in the Cenozoic era and the ranges of important groups of fossils that date from it;
i) list ways in which the fossil record reveals paleogeographical information in each of the eras studied;
j) describe and sketch important fossils for each of the following: poriferans, coelenterata, bryozoans, brachiopods, molluscs, arthropods, echinoderms, vertebrates (2a);
k) explain how the fossil record relates to the theory of biological evolution;
l) examine one major fossil-bearing area or zone in detail;
m) differentiate between Saurischian and Ornithichian dinosaurs;
n) explain the "explosion of life" at the beginning of the Cambrian period in light of an unconformity and the Ediacaran fauna.

2. Student Activities

Students are to:

a) carry out laboratory exercises, including sketches, with fossils or field studies from outcrops;
b) apply the principle of superposition to stratigraphic exercises;
*c) perform a laboratory exercise to illustrate radioactive decay or half-life;
*d) construct a linear time graph or a present-day calendar-year graph of geological history, indicating the major subdivisions of time and significant physical and biological events (8c);
e) research contemporary paleontological topics (5c).

3. Applications

a) Sedimentary rocks, both in subsurface and surface exposures, are usually correlated on the basis of their lithology and fossils.
b) Fossils provide a guide to the sequence of events in earth history.
c) Petroleum geologists use fossils in the search for oil and gas because of their value in the correlation of strata and the interpretation of depositional environments and as indicators of thermal maturity in sedimentary basins.
d) Economic geologists use fossils in similar ways in their search for mineral deposits in sedimentary basins.
e) The relative Geologic Time Scale, based on fossil successions, gives geologists a time framework for earth processes.
f) Fossils contribute evidence in the study of evolution.

4. Societal Implications

a) Petroleum and the great number of petroleum by-products contribute to our high standard of living.
b) Fossil fuels are an important and a non-renewable source of energy for today's industrial society.
c) Research continues to increase our ability to answer the age-old questions concerning the earth and life on earth.

5. Evaluation of Student Achievement

At least 30 per cent of the term mark for this unit is to be based on students':

a) laboratory or field work;
b) qualitative laboratory work in activity 2a;
c) information obtained from library research;
d) identification of some common fossils.

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*See the subsection entitled "Student Activities" on page 5.

6. Safety Considerations

a) Students should be instructed in the proper use of dilute hydrochloric acid and other chemicals.
b) Students should be cautioned to exercise care on field trips (e.g., to be aware of traffic at road cuts and falling rocks at cliff faces).
c) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) research the theories on mass extinctions;
b) examine the evidence for warm-bloodedness (endothermy) in dinosaurs;
c) research the theories on the origin of life;
d) discuss the relationship of the supercontinents of the past to the events of that time;
e) research one of the "living fossils", such as the coelacanth;
f) discuss the impact of unconformities on the record of the past;
g) research the geological record of *Homo sapiens*.

8. Some Teaching Suggestions

a) Laboratory exercises should be designed so that students are required to handle and sketch fossils.
b) Students should be encouraged to name and describe the features of at least ten to fifteen fossils.
c) Exercises should be designed to illustrate the enormity of geological time and to indicate the relatively recent appearance of the higher forms of life.
d) The relationships of sedimentary rocks to their environments should be reviewed.
e) Students should be introduced to the change in the Proterozoic-Paleozoic boundary.
f) The usefulness and limitations of theories should be stressed.

Core Unit 6

Clocks for the Rocks

Time: 5 hours

Since a dynamic earth is a changing earth, our picture of the earth is a historical one, and the fundamental component of this picture is time. We are surrounded by indicators of time: layers of rocks, tree rings, erosion and deposition, radioactive minerals, and other geological processes. These data are the keys to grasping the magnitude of the time frame through which the earth has developed, and hence the keys to understanding geology and interpreting geological processes. The purpose of this unit is to provide students with opportunities to understand the techniques for determining how much time was involved in the development of the earth and the significant contribution of geology to this determination.

This unit may be divided into topics such as the following:

- Review of terminology and elementary concepts (particularly from core unit 5)
- Relative dating
- Radioactive (isotopic) dating

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a curiosity about the measurable events of the earth's geological history (2a);
b) an appreciation for the concept of geological time and for the importance of its measurement in geology (3a-3d);
c) an appreciation for the necessity of correlating events within the solar system (3d);
d) a questioning attitude towards geological dating, which, like other scientific models, is tentative and subject to change (2c, 8a).

Skills. Students will have the opportunity to develop skill in:

a) solving numerical problems relating to geological time (2b-2d);
b) graphing data derived through laboratory investigations (2b, 2c, 8b);
c) organizing data pertaining to geological age into a time scale (3a, 3d);
d) inferring the nature of past environments on the basis of evidence presented by geological dating (3b, 3d);
e) predicting future geological occurrences on the basis of records of past history (3d).

Knowledge. Students will be expected to:

a) explain the meaning of the following terms: relative time scale, absolute time scale, stratigraphic superposition, geological column, varve, dendrochronology, natural radioactivity, isotope, radioactive decay, half-life;
b) differentiate between relative and absolute geological dating methods (2a-2d, 5a, 5b);
c) describe and explain the following techniques used for relative geological dating and state the strengths and weaknesses of each method: varves, salt accumulation, tree rings, rate of deposition, rate of erosion (2a, 5b);
d) describe and explain the various techniques for isotopic age determination, stating the isotopes, their half-life, the effective dating range, and some materials that can be dated (2b-2d, 5b, 8a-8c);
e) explain how a given event or formation may require a specific dating technique (8a);
f) indicate how geological dating helps to explain the earth's chronology (3c, 3d).

2. Student Activities

Students are to:

a) explain and evaluate various techniques of relative dating;
*b) perform an experiment or computer simulation to illustrate radiometric decay and half-life (5a, 5c, 8a);
*c) draw a typical decay curve to predict half-life (5c);
d) construct a chart to show isotopic age determination (5b, 8c).

3. Applications

a) Carbon 14 dating and dendrochronology can be used to establish a time frame for archeological sites.
b) A knowledge of sedimentation or erosional rates can assist in shoreline management and other water-control measures.
c) Correlation is a useful technique in the search for certain minerals.
d) Radiometric dating provides a basis for the correlation of worldwide historical geological events.

4. Societal Implications

The reconstructing of past environments reveals periods of climatic change; this information is useful in projecting future climatic trends.

5. Evaluation of Student Achievement

At least 40 per cent of the term mark for this unit is to be based on students':

a) proficiency in doing investigations and calculations;
b) written explanations of geological dating applications;
c) accuracy in solving problems and drawing graphs.

6. Safety Considerations

There are no special safety considerations for this unit.

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*See the subsection entitled "Student Activities" on page 5.

7. Possible Extensions

Some students might:

a) use a Geiger counter and test a sample of rock for degree of radioactivity;
b) obtain a core sample and study local varves;
c) research the methods and equipment used in isotope dating;
d) arrange a field trip to a local university or another research facility that does isotope dating;
e) perform a laboratory exercise on isotope dating, using actual isotope percentages and concordance curves;
f) investigate radioactive decay, considering alpha and beta particles and gamma rays.

8. Some Teaching Suggestions

a) The usefulness and limitations of dating techniques should be stressed.
b) The use of graphs and diagrams to illustrate geological dating methods should be emphasized, particularly for those methods for which no activities have been indicated.
c) The following points should be included among the requirements for measuring time: (i) the rate at which the process is taking place today, (ii) the variation of the rate during the interval of time being measured, (iii) the total change effected by the process during the time interval.

Core Unit 7

Geological Maps and Illustrations

Time: 6 hours

Geological maps and illustrations are an important part of the accumulated knowledge about the composition and structure of the earth's crust. They contain information that cannot be as easily and fully expressed by any other means and, as a result, reflect the importance of field work. By using a symbolic language, geologists are able to depict relationships that are too large to be taken in with a single glance. This three-dimensional information is important to engineers and workers in construction-related industries. The purpose of this unit is to provide students with opportunities to investigate the techniques used in the creation of geological maps and to illustrate the value and applications of geological maps and illustrations (sections).

This unit may be divided into topics such as the following:

- Topographic and surface geological maps
- Horizontal rock strata
- Vertical and inclined strata
- Folded strata
- Faulted strata
- Stratigraphic columns

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the variety of applications of geological maps and illustrations (2b, 3a-3c);
b) a confidence and satisfaction in using process skills (2g, 5c);
c) an appreciation of the value of manual skills in presenting geological data (2a-2g).

Skills. Students will have the opportunity to develop skill in:

a) gathering data from various sources;
b) plotting data on maps (2a);
c) measuring and plotting the attitude (strike, dip, and pitch) of a rock bed (2b, 2c);
d) using the symbols commonly employed to show structure on geological maps (2g);
e) visualizing three-dimensional objects from air photos and topographic maps;
f) making inferences from geological maps and cross sections (2b, 5c);
g) making hypotheses based on geological maps and sections (5c).

Knowledge. Students will be expected to:

a) explain the meaning of the following terms: map scale, contour line, contour interval, latitude, longitude, drainage, military grid system, geological map, strike, dip, pitch, anticline, syncline;
b) draw accurate topographical profiles and calculate vertical exaggeration (2a, 2b);
c) label the elements of a fold and a fault (2a, 2c, 2e);
d) explain geological cross sections (2a, 2b);
e) correlate stratigraphic columns (2f, 2g, 8c);
f) construct block diagrams of geological structures (2e-2g, 8a).

2. Student Activities

Students are to:

*a) draw topographical profiles and calculate vertical exaggeration (5a);
*b) draw geological cross sections (5b);
c) measure dip and strike;
d) draw fence diagrams, given a series of stratigraphic columns;
e) draw simple block diagrams, for example, of inclined strata, synclines, and anticlines;
f) show appropriate geological symbols on maps and diagrams;
g) interpret geological sections (5c).

3. Applications

a) Geological maps and sections are a convenient means of presenting a vast amount of data.
b) Geological maps and cross sections are used to locate favourable sites for construction and resource exploration and development.
c) Topographical maps, geological maps, and air photographs are used to locate rock outcrops and structures and to plan and carry out the preliminary exploration of an area.
d) Geological cross sections are used in the mining industry to plan a safe and efficient development of the ore body.

4. Societal Implications

a) Geological and topographical maps are useful in urban development because they help to identify suitable sites for buildings, roads, and utilities.
b) Geological maps and cross sections are used in mineral and oil and gas explorations and development. The use of these maps and cross sections increases the success ratio of exploration and the efficiency of development and production.

5. Evaluation of Student Achievement

At least 60 per cent of the term mark for this unit is to be based on students':

a) drawings of geological maps and cross sections;
b) drawings and measurements of strike and dip and drawing of simple three-dimensional diagrams that show vertical and inclined strata, anticlines, and synclines;
c) interpretations of air photographs, topographical maps, and diagrams.

6. Safety Considerations

The safety precautions that are necessary for this unit are those normally exercised in the classroom. For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

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*See the subsection entitled "Student Activities" on page 5.

7. Possible Extensions

Some students might:

a) determine the heights of objects from stereoscopic photographs;
b) research a mine and construct a model geological section of it;
c) plot the drill-hole intersections of a mine;
d) discuss subsurface contours;
e) investigate isograds and isopleths;
f) observe and analyse selected stereoscopic air photographs with a stereoscope.

8. Some Teaching Suggestions

a) The use of visual media and models to reinforce the three-dimensional aspect of geological structures is helpful.
b) Students should have opportunities to construct outcrop maps and geological cross sections.
c) Students should be encouraged to construct stratigraphic sections (fence diagrams).

Core Unit 8

Environmental Geology

Time: 7 hours

The environment is a dynamic system. Geological changes occur naturally on both a continuous and a catastrophic basis. In addition, human activity itself has become a major agent of geological change. Environmental geology allows us to assess the role that humans play in such change. The purpose of this unit is to provide students with opportunities to investigate the environment from a geological perspective, to consider humans as geological agents, and to consider the dilemma that our small planet faces with limited resources on the one hand and the ever-increasing demands of population and society on the other.

This unit may be divided into topics such as the following:

- Humanity as a geological agent
- The resources problem
- Increasing demands for resources versus the need for conservation
- The search for alternative resources

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a respect for the natural environment and an awareness of its dynamic structure (2a-2h);
b) an awareness that our knowledge of the earth can and should be applied to our activities, both present and future (2c-2h);
c) a concern for the environmental hazards that are predictable and that can thus be avoided (2c-2f);
d) a concern for the possible adverse effects of the environmental modifications imposed by society (2a-2h);
e) a commitment to the maintenance of our natural environment (2a-2h).

Skills. Students will have the opportunity to develop skill in:

a) predicting the environmental response to the current sustained activities of humans (2a-2h);
b) interpreting, from geological maps, information that indicates potential environmental hazards (2a, 2d, 2f, 2g);
c) evaluating the negative impact of a geological event on the environment and relating the magnitude of the event to the impact (2e, 2f);
d) projecting the human response that would be required to deal with an event that presents an environmental hazard (2f-2h);
e) analysing the possibilities of, and methods of exploiting, alternative sources for (or techniques for dealing with) our finite resources (2h);
f) making decisions on the basis of an analysis of priorities and of the problem of human demands versus conservation (2g).

Knowledge. Students will be expected to:

a) explain the meaning of the following terms: renewable resources, non-renewable resources, mass wasting, low-grade minerals, toxic rain;
b) state possible actions for the rehabilitation of abandoned quarries and open-pit mines (2b, 2g);
c) explain the principles involved in the occurrence of landslides (2f, 2g);
d) describe methods to control or prevent shoreline erosion and flooding (2a, 2f);
e) identify the factors that cause flooding within a drainage basin (2a);
f) briefly explain the role of various types of pollutants in modifying the environment (2d, 2g);
g) describe and explain alternatives to presently used methods and practices with respect to the conservation of resources (2h).

2. Student Activities

Students are to:

a) predict the total impact that a power dam would have on the environment, given a detailed outline of a drainage basin on a topographical map (3a);
b) establish, for an abandoned quarry site, a rehabilitation program that is compatible with the surrounding land use;
*c) analyse the processes of shoreline erosion, showing methods of control (3b);
*d) trace the total effect that an emission of a substance such as sulphur or carbon oxides would have on the natural environment (3a, 3c);
*e) determine, through analysis, the impact that a major catastrophic event, either natural or caused by humans, would have on the environment, using quantitative data where possible (3b);
f) perform a land-use study of an urban centre that is susceptible to catastrophic geological activity to investigate the residents' awareness of the problem and their response (3a);
*g) prepare a report concerning an environmental hazard not discussed in class, with the focus on environmental protection (3b);
*h) prepare a report outlining the dilemma created by the demands of modern society and the need for solid conservation practices and examine possible solutions to the demand-versus-conservation dilemma (3a, 3c).

3. Applications

a) A knowledge of geology is useful in making both short-term and long-term decisions pertaining to the environment.
b) We can minimize natural hazards by choosing not to locate future development in high-risk areas.
c) A recognition of the constraints that the earth places on our exploitation of it is the first step in developing opportunities for continued growth through effective land, water, and air management.

4. Societal Implications

a) We live on a small planet with limited resources. Through techniques such as oceanographic surveys, satellite monitoring, and climatic studies, we must monitor activities on the earth.
b) As our knowledge of earth science grows, our ability to devise means of applying data and of monitoring the earth will increase.
c) Earth science becomes increasingly important as we place greater and greater demands on the earth to maintain our standard of living.
d) As people continue to concentrate in cities, earth science becomes increasingly important in helping to maintain an acceptable environment.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) appropriate use of data or graphing in activities 2c to 2e;
b) written or oral reports produced for the remaining activities.

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*See the subsection entitled "Student Activities" on page 5.

6. Safety Considerations

The safety precautions necessary for this unit are those normally exercised in the classroom or field situation. For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) test the pH values of natural waters for the effects of acid rain;
b) participate in a local field trip designed with an emphasis on environmental geology;
c) investigate the factors involved in the selection of toxic-waste sites;
d) research alternative energy sources that will help to ease our dependence on non-renewable sources;
e) investigate the problems associated with agricultural pollution.

8. Some Teaching Suggestions

a) In view of the time allotted for this unit, it would be appropriate to use group work and class discussions to deal with several of the chosen topics.
b) Case studies (e.g., the Turtle Mountain landslide, the James Bay power project) should be used when possible for both the student activities and class discussions.

Core Unit 9

The Ontario Record

Time: 5 hours

Ontario is divided into three major geological regions: the Precambrian Shield, the St. Lawrence Platform, and the Hudson Platform. The purpose of this unit is to provide students with a general overview of the geological data base of the province. The unit may be divided into topics such as the following:

- The Precambrian Shield
- The St. Lawrence and Hudson platforms
- Glacial features of Ontario

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a curiosity about the origin of the geological structure of Ontario (2a-2d);
b) an appreciation of the fact that the geological record of Ontario is far from complete in relation to the record of North America as a whole (2a);
c) an appreciation of Ontario's glacial history and its relation to the physiographic features of the province (2f, 3c, 3d).

Skills. Students will have the opportunity to develop skill in:

a) interpreting the geological history of Ontario from geological maps and diagrams (2a);
b) classifying mineral deposits in relation to host rocks (2a, 2b).

Knowledge. Students will be expected to:

a) explain the meaning of the following terms: Shield, orogeny, geological province, peneplain, graben, unconformity, cuesta, escarpment, Pleistocene;

b) identify and explain such prominent geological features as the Canadian Shield, the geological provinces of the Shield, the Grenville Front, the Frontenac Axis, the Ottawa-Bonnechere Graben, the Great Lakes–St. Lawrence Lowlands, the Hudson Bay Lowlands, and the Niagara Escarpment (2a);
c) describe and explain some major geological events relative to Ontario's three major geological regions and their associated rock types (2a, 2d);
d) establish the role of bedrock in controlling the distribution of such features as the Great Lakes, the Ottawa River, the Niagara Escarpment, and Niagara Falls (2e).

2. Student Activities

Students are to:

*a) prepare a map of Ontario, outlining the major geological areas, their rock types, and the estimated age of each (3a);
b) prepare a mineral location map of Ontario and relate it to the geological map of Ontario (3a);
c) identify the major geological features in the vicinity of their school;
*d) draw a diagram (stratigraphic column), using records from bore-holes, to illustrate the bedrock that underlies southern Ontario (3b, 3d);
*e) research a prominent geological feature of Ontario, establishing the role of bedrock in the feature;
f) prepare a map and a brief description of the general glacial pattern of Ontario (3c, 3d).

3. Applications

a) A knowledge of rock types and structures provides us with an insight into the location of potential mineral resources, both renewable and non-renewable.
b) A knowledge both of bedrock and its distribution beneath glacial deposits and of glacial history is essential to an understanding of water supply and drainage patterns.
c) Variations in glacial deposits dictate land uses.
d) The suitability of locations for waste and toxic-material disposal depends on the properties of the bedrock and glacial deposits at these locations.

4. Societal Implications

a) Ontario's industrial and urban centres are highly dependent on various geological resources. Exploration in the field and research in the laboratory must continue if reserves of both renewable and non-renewable resources are to be maintained.
b) The disposal of industrial and urban waste and toxic materials requires a knowledge of earth materials.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students' map work, research, and laboratory records.

6. Safety Considerations

The safety precautions necessary for this unit are those normally exercised in the classroom or field situation. For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) research the extent of the Canadian Shield in North America;
b) research the presence and development of hydrocarbons in the platform rocks;
c) research the application of the plate tectonics model to the Canadian Shield;
d) participate in a field trip to local geological features.

8. Some Teaching Suggestions

a) This unit, along with two optional units, may form a strong local unit.
b) Many of the statistical data needed for this unit are available from both provincial and federal government publications.

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*See the subsection entitled "Student Activities" on page 5.

Optional Unit 1

The Precambrian Shield

Time: 6 hours

Geologists indicate that the Precambrian era represents more than four-fifths of the earth's history. It began with the formation of the earth and its oldest known rocks; it ended some 670 million years ago with the deposition of the earliest Paleozoic strata. The Shield, which covers about two-thirds of the surface area of Ontario, is composed primarily of granitic gneisses. These Shield rocks, the result of massive lava flows, sedimentation, and metamorphism, were formed and deformed as the Shield grew by accretion. The last of these accretionary events was the addition of the Grenville to the Superior Province, beginning about 1150 million years ago. As these new structural units were added to the Shield, a mosaic composed of seven distinct geological provinces was built. Within these ancient rocks, usually associated with volcanism, are the metallic ores that are of such great value to Ontario's economy.

This unit may be divided into topics such as the following:

- Early earth
- The origin and formation of the Shield
- The structural units of the Shield
- The economic importance of the Shield

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a curiosity about the early events in the earth's history;
b) an appreciation of the complexity of the problem of determining the different stages (eras) of Precambrian time;
c) an appreciation that early plate tectonics probably played a significant role in the formation of the Shield;
d) an appreciation of the economic wealth derived from the Canadian Shield in Ontario (2d, 8a);
e) an open-mindedness towards the different theories proposed for the Sudbury Basin and its minerals (2e).

Skills. Students will have the opportunity to develop skill in:

a) plotting data on a map of Ontario and of Canada (2a, 8a);
b) inferring impact craters from topographical and geological maps;
c) organizing, in sequence, the events in Precambrian time (2b, 2c).

Knowledge. Students will be expected to:

a) explain the meaning of the following terms: magmatic differentiation, accretion, greenstones, stromatolites, the Grenville Province, chert formation;
b) describe and explain astronomical events that are proposed as having occurred during the initial stages of the earth's formation (2b);
c) recall the extent of Precambrian time, how it is defined, and why it is difficult to decipher (2c);
d) indicate the location and age of the geological provinces on a map of Canada (2a);
e) state, according to accepted geological theory, how and when the oceans and atmosphere formed (2b, 7a);
f) list the main types of Shield rocks (2c);
g) describe and explain the Precambrian fossils found in the Shield rocks (2b);
h) name some common minerals associated with the Shield and indicate where they are found (2d, 8a).

2. Student Activities

Students are to:

*a) plot the geological provinces and their proposed ages on a map of Canada (3b);
b) describe possible origins of the earth, the oceans, and the atmosphere;
c) examine the geological development of the Shield and, as far as possible, apply the theory of plate tectonics (3b, 8b);
d) analyse the importance of mining to Ontario's economy;
*e) write a report based on the case history of at least one Ontario mining district, such as Sudbury, Cobalt, Hemlo, Blind River, or Timmins (5a).

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*See the subsection entitled "Student Activities" on page 5.

3. Applications

a) New ore-body locations can be inferred from what is known about present ore bodies in the Precambrian rocks of Ontario.
b) The application of the plate tectonics model to the Shield provides a new and fuller understanding of the Shield's development. This understanding can be applied to the search for minerals.
c) Our knowledge of primitive life in Precambrian time can be applied to a search for extraterrestrial neighbours in space.

4. Societal Implications

a) Miners and their families suffer dislocation problems when ore bodies become "worked out" or when the supply of and demand for specific minerals change.
b) Pollution and health problems are created by mining and smelting operations.
c) New technology that is being developed will increase the rate at which ore can be removed from the ground, thus shortening the life of a mine and, in some cases, eliminating the need to build a townsite near new mine locations.

5. Evaluation of Student Achievement

At least 30 per cent of the term mark for this unit is to be based on students':

a) written or oral reports dealing with the case history of one mining district in Ontario;
b) plotting of a map of Canada's geological provinces and application of the theory of plate tectonics.

6. Safety Considerations

No special safety precautions are necessary for this unit.

7. Possible Extensions

Some students might:

a) discuss the effects of glaciation on the Shield;
b) research the possibility of finding diamonds in the Shield;
c) research the origins of the Shield, including an in-depth analysis of the role of plate tectonics and continual growth by accretion.

8. Some Teaching Suggestions

a) The publication *Rocks and Minerals of Ontario*, available from the Ministry of Northern Development and Mines, is an excellent resource for this unit.
b) Students can plot the occurrences of minerals on a geological map of Ontario to show the relationship between each mineral and the type of its host rock.
c) Although it is still somewhat tentative, new evidence is gradually indicating that the structural provinces of the Shield are a product of early plate movement. This information will allow students to recall the processes related to plate tectonics and to appreciate the practical applications of the theory, not only in helping to explain geological structures, but also in the search for ore bodies related to plates and plate boundaries.
d) Students can write reports on mining (e.g., its importance to the economy, mining districts) in the Shield. They should consider the benefits to Canada, employment opportunities, dislocation of families, and environmental issues that arise from mining.
e) The use of visual media to reinforce the economic aspects of mining is important.

Optional Unit 2

Paleozoic Rocks

Time: 6 hours

The Paleozoic rocks that overlap the Precambrian Shield have been formed by extensive sedimentation processes. At one time these rocks were much more extensive; at present they are concentrated in two major areas, the Hudson Bay Lowlands (Hudson Platform) and the St. Lawrence Lowlands (St. Lawrence Platform). The Paleozoic era, which followed the Proterozoic, may have lasted for over 400 million years. The purpose of this unit is to provide students with opportunities to examine the extent of Paleozoic rocks in Ontario, to review and develop further their understanding of the petrology and paleontology associated with the formation of the Lowlands, and to carry out an evaluation of the economic significance of the Paleozoic rocks in Ontario.

This unit may be divided into topics such as the following:

- The extent of the Paleozoic rocks in Ontario
- The Paleozoic era as recorded in the rocks of Ontario
- The Niagara Escarpment
- Economic resources from the Paleozoic rocks

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the events that have marked the geological history of Ontario (2b, 2c);
b) a questioning attitude towards the evidence used to interpret the geological events that have shaped Ontario (2a, 2c);
c) a respect for the geological diversity of Ontario (2a, 2c, 2e).

Skills. Students will have the opportunity to develop skill in:

a) plotting data on maps to delineate geological boundaries (2a);
b) constructing scale columnar geological sections (2b);
c) interpreting geological information to determine a sequence of events (2b, 2c, 2e).

Knowledge. Students will be expected to:

a) explain the meaning of the following terms: unconformity, Shield rocks, Platform rocks, differential erosion, caprock, evaporite, carbonate rocks, Michigan Basin, cuesta, the law of superposition;
b) state the geological time periods contained within the Paleozoic era (2b);
c) recognize the predominant rock formations that have characterized each period of the Paleozoic era (2a, 2b);
d) apply the law of superposition to interpret a succession of sedimentary rock layers (2b, 2c);
e) describe the economic significance of the resources derived from the Paleozoic rocks, particularly the following: oil, gas, coal, oil shales, lime, salt, gypsum, aggregate, and building stone (2d);
f) explain the formation, extent, and stratigraphy of the Niagara Escarpment and the impact that it has had on southern Ontario (2b, 2c, 2e).

2. Student Activities

Students are to:

*a) delineate the divisions of Paleozoic rocks on a map of Ontario (5);
*b) construct a generalized columnar geological section of southern Ontario (5);
c) construct paleoenvironments for the Paleozoic era based on rock type and fossil content (5);
*d) construct a map to show the economic activities taking place on the Paleozoic Platform (5);
e) explain the formation of the Niagara Escarpment in terms of differential erosion.

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*See the subsection entitled "Student Activities" on page 5.

3. Applications

a) Fossil evidence preserved in Paleozoic rocks provides a key to the theory of evolution.
b) Information gained through the study of one rock section can be correlated to other locations to determine economic possibilities.

4. Societal Implications

a) Development occurring in areas with unique features, such as the Niagara Escarpment, must be controlled to maintain aesthetic value.
b) Caution must be exercised when abandoned salt mines are used as storage facilities for natural gas.
c) Access to abandoned mines must be controlled.

5. Evaluation of Student Achievement

At least 30 per cent of the term mark for this unit is to be based on students' mapping and construction exercises.

6. Safety Considerations

a) Students should be cautioned to exercise care on field trips.
b) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) construct a fence diagram as an extension of activity 2b in order to illustrate the rock sequence from the Ordovician to the Devonian period;
b) explain the significance of the Michigan Basin in the formation of the escarpments of southern Ontario;
c) explain the change in thickness and the eventual disappearance of some strata as shown on a fence diagram of the Niagara Escarpment;
d) plot and explain the location of quarry operations in Ontario;
e) locate oil or gas wells or salt mines and determine with which rock formations they are associated;
f) determine the policies of the Ontario government concerning aggregate-pit rehabilitation;
g) indicate locations of oil shales in eastern Ontario;
h) construct a flow diagram to illustrate the operation of a limestone quarry or a salt mine;
i) organize a field trip to a quarry, mine, or processing plant to study rock formations, fossil types, or the economic impact of Ontario's rocks.

8. Some Teaching Suggestions

a) The publication *Rocks and Minerals of Ontario*, available from the Ministry of Northern Development and Mines, is an excellent resource for this unit.
b) Hand samples and effective visual aids should be available to illustrate rock and fossil types.
c) The teacher and students should agree to a common scale for the construction of columnar diagrams to maintain a degree of uniformity in the exercise.
d) The relationship between the Paleozoic and Precambrian eras and the associated unconformity should be emphasized.

Optional Unit 3

Glacial Terrain

Time: 6 hours

The physiography of Ontario is the product of two factors: the underlying bedrock and the effects of the Pleistocene Ice Age. The Ice Age, including both the actual glaciation advances over the landscape and the effects of the deglaciation, represents the final major event in the geological development of Ontario. The purpose of this unit is to provide students with opportunities to review the fundamentals of glaciated landscapes from core unit 9, to investigate the processes and products of glaciation, and to understand that the basic patterns of relief and drainage that are evident in Ontario today owe their existence to the Wisconsin glacial period.

This unit may be divided into topics such as the following:

- The causes of past ice ages
- Is another ice age coming?
- The Pleistocene epoch
- The extent and nature of continental glaciation
- The glaciation and deglaciation of Ontario

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an open-mindedness towards the presentation of a new theory;
b) an appreciation of the impact that the Ice Age has had on the physiography of our continent;
c) a questioning attitude towards a possible future ice age.

Skills. Students will have the opportunity to develop skill in:

a) evaluating theories on the origins and possible reoccurrence of an ice age (2f);
b) interpreting from air photographs and topographical maps the evidence left by glaciation and deglaciation (2a, 2b);
c) inferring glacial behaviour and effects from diagrams and slides (2d, 2f).

Knowledge. Students will be expected to:

a) explain the meaning of the following terms: Pleistocene epoch, Wisconsin advance, firn or névé, continental glacier, alpine glacier, glacial tills, erosional features (e.g., roches moutonnées, striae), depositional features (e.g., ground moraines, drumlins);
b) state the theories proposed by glaciologists to explain the occurrence and movement of continental glaciers (2f);
c) describe the extent of glaciation in North America (2a, 2f);
d) describe and explain the formation of glacial ice and glacial flow (2c);
e) describe and explain the features associated with continental glaciation, indicating their erosional or depositional origin (2d);
f) analyse the significance of the Wisconsin period to the economic development of Ontario;
g) briefly describe the contribution of Louis Agassiz to the development of glaciology.

2. Student Activities

Students are to:

*a) analyse an aerial photograph or a topographical map of a selected area (5a);
*b) identify from air photos, slides, or diagrams the glacial features mentioned above (5a);
*c) investigate the conditions necessary for the formation and advance of glacial ice and the global occurrence of ice fields and glaciers;
d) construct a chart of glacial features, describing their formation and morphology (8d);
e) identify the extent of glaciation in North America;
f) discuss the possibility of another ice age and the impact it would have on our civilization (5b, 8c);
g) discuss the implications of a warming climate and the melting of the polar ice caps (5b, 8c).

3. Applications

a) The nature of the deposition that resulted from glacial activity in the southern portions of Ontario has influenced land use.
b) The erosion of the Canadian Shield by glacial advance has, in some cases, simplified the exploration for, and recovery of, minerals.

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*See the subsection entitled "Student Activities" on page 5.

4. Societal Implications

a) The presence of ground ice and permafrost constantly reminds us that the renewal of glacial activity is very possible.
b) Any climatic change, whether to colder or warmer conditions, will have far-reaching effects on human activity.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) map, photo, or diagram interpretations;
b) participation in class discussions;
c) performance on review and identification tests.

6. Safety Considerations

No special safety precautions are necessary for this unit.

7. Possible Extensions

Some students might:

a) differentiate between warm and cold glaciers;
b) compare alpine to continental glacial features;
c) map the sequence of glacial periods according to marginal evidence;
d) research isostatic rebound after deglaciation;
e) examine the environment in a periglacial landscape;
f) research the occurrence of ancient ice ages;
g) organize a field trip to a well-defined glacial area.

8. Some Teaching Suggestions

a) It is advisable to focus on glacial activity in the local area, since an analysis of the overall glacial pattern of Ontario would be very complex.
b) The Peterborough region offers an ideal area for a case study, because it is located near the meeting point of the resistant Precambrian erosion surface and the sedimentary Paleozoic lowlands.
c) Student attention should be focused on climatic trends and related events in discussing the Ice Age.
d) Students could chart glacial features under the following headings: (i) Evidence of Ice Erosion and (ii) Evidence of Ice Deposition (glacial till and fluvioglacial, glaciolacustrine, glaciomarine, and aeolian deposits).

Optional Unit 4

The Great Lakes

Time: 6 hours

The Great Lakes are a recent addition to our geological heritage, a product of the last ice age. Before the Pleistocene era, the area was a lowland, carved by rivers flowing northward towards Hudson Bay. During the Pleistocene era, the ice sheets advanced, following the basins and deepening them as they went. During deglaciation the shape of the lakes and their outlets constantly changed as the position of the ice front changed. Today we can see the former shorelines of the lakes, in some cases well above the present lake levels. The great weight of the Laurentide ice sheet had depressed the land and, as deglaciation continued, the rebound began, a process that continues today. The purpose of this unit is to provide students with opportunities to understand the formation of the Great Lakes, their continuing development, and the need to preserve their vast potential as a resource for the thirty-seven million people clustered around their shores.

This unit may be divided into topics such as the following:

- The geological development of the Great Lakes
- Shoreline processes and fluctuating lake levels
- The effect of engineering structures on shoreline processes
- Land-use zoning of shorelines

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the geological processes that have created the Great Lakes (2a);
b) a questioning attitude towards the present uses of the Great Lakes (2a).

Skills. Students will have the opportunity to develop skill in:

a) interpreting from maps or air photographs the evidence for the ancestral Great Lakes (2a, 2b);
b) obtaining evidence for crustal tilting following the retreat of the last glaciers (2d);
c) identifying the effect of crustal tilting on the development of the Great Lakes and its effect on the lakes today (2d);
d) obtaining, organizing, and analysing data from lake-level gauges (2b, 2e);
e) gathering and interpreting historical data, such as maps and photographs, to demonstrate the change in shorelines in a given area and deducing the reasons for the change (2b, 2c, 2e).

Knowledge. Students will be expected to:

a) define the following terms: Pleistocene epoch, Wisconsin period, raised beaches, isostasy (postglacial rebound), spillways, spits, bars, hooks, long shore currents;
b) identify the principal geographic, geological, hydrographic, and bathymetric features of the Great Lakes (2a);
c) explain the evidence that is used to decipher the development of the Great Lakes over the past 15 000 years (2b);
d) list the factors involved in the changing patterns of the glacial Great Lakes, particularly with respect to shorelines (2a, 2d);
e) indicate the former shorelines of these glacial lakes (2b);
f) identify those shoreline environments that are susceptible to severe erosion (2c, 2e);
g) apply a knowledge of shoreline environments to the land-use zoning of one of the Great Lakes (2c).

2. Student Activities

Students are to:

*a) interpret topographical maps or air photographs as an aid to summarizing the history of the Great Lakes (5a);
*b) map the raised beaches and glacial Great Lakes (5a);
*c) examine both ground-level and air photographs to determine shoreline processes and the effect of engineering structures on these processes (5a);
*d) explain a contour map to illustrate the rate of present-day crustal tilting (5a);
*e) write a report on either coastal-environment erosion and shore damage or the problems involved in controlling lake levels (5b).

3. Applications

a) A knowledge of the behaviour of the waters of the Great Lakes and the patterns that they follow is essential for shoreline management and development.
b) A knowledge of coastal processes is essential for land-use planning along the shores of the Great Lakes.
c) A knowledge of crustal tilting is essential in planning megaprojects on the Great Lakes.

4. Societal Implications

a) Information on the Great Lakes can help people form reasoned opinions on how they can be maintained as a multiuse natural resource.
b) An understanding of the problems that can arise if waters are diverted from the Great Lakes, causing a reduction of lake levels, can help society deal with the many schemes proposed to divert water from the lakes.

5. Evaluation of Student Achievement

At least 40 per cent of the term mark for this unit is to be based on students':

a) drawing and interpretation of maps and photographs;
b) written papers.

6. Safety Considerations

a) Care must be taken if a trip to the shoreline is planned. The rules of water safety must be obeyed.
b) Steep or undercut cliffs should be avoided on field trips.
c) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) discuss the use of fossil pollen or other paleontological evidence and sediment samples to establish a chronology for lake histories;
b) describe the use of geophysical techniques for mapping the bottoms of the Great Lakes;

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*See the subsection entitled "Student Activities" on page 5.

c) visit a beach or lake to study a beach profile and note the sorting of sedimentary particles that make up the beach and the shoreline;
d) research, in detail, the chronology of the glacial Great Lakes;
e) explain, in detail, the use of carbon 14 in establishing the time frame for the geological history of the Great Lakes.

8. Some Teaching Suggestions

a) Part of the classroom wall could be used for displaying news items relating to the Great Lakes.
b) Students could visit the offices of those municipalities that are concerned with shoreline properties along the Great Lakes.
c) Students could examine the percentage of overall property damage attributable to shoreline damage.
d) The use of audio-visual material would enhance the illustrations showing the dynamic shoreline processes.

Optional Unit 5

Drainage Basins

Time: 6 hours

Every stream and, in fact, every segment of a stream has its own drainage basin. The drainage basin is the total area that contributes water to the stream. Drainage basins are separated from one another by a drainage divide.

Streams play a significant role in the cutting of valleys; however, sheet erosion and the mass wasting of weathered rock material also contribute to the formation of valleys. These processes form a part of the geological cycle, which has been described as a sequence of forms, essentially valleys and hills, through which a land mass is thought to change from the time it begins to be eroded until it is reduced to near base level. The purpose of this unit is to provide students with opportunities to review the hydrologic cycle, to examine a typical drainage basin and its river system (or watershed) as a part of the geological cycle, and to understand that drainage basins form a natural unit for land-use and resource planning.

This unit may be divided into topics such as the following:

- The hydrologic cycle
- Drainage basins and the geological cycle
- The geometry of rivers

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the cycle of a drainage basin;
b) an appreciation of the effect of human development on fluvial events;
c) a commitment to working towards the environmental enhancement and preservation of local watersheds.

Skills. Students will have an opportunity to develop skill in:

a) relating the hydrologic cycle to the development of a drainage basin (2a, 5a);
b) determining the stream profile of the trunk stream in a drainage basin and analysing its shape from a topographical map (2b, 5b);
c) identifying the sediment load of a river and its mode of transport and deposition (2c, 2e, 2h);
d) identifying the variables in a river, such as its gradient, width, depth, velocity, discharge, sediment load, and meander belt (2b, 2c, 2f-2h, 5b);
e) classifying drainage systems to illustrate the role of topography in the river system (2c, 5b);
f) identifying the headwaters, flood plain, and base level of a drainage basin (2b, 5b);
g) classifying river deltas (2g).

Knowledge. Students will be expected to:

a) define the following terms: drainage basin or watershed, drainage divide, water cycle, discharge, stream profile, stream velocity, sediment load, dentritic, trellis, annular drainage basins, meander, sinuosity, delta;
b) recognize the shape and form of a drainage basin (2b);
c) compare the fluvial functions of the headwaters, flood plain, and base level in a drainage basin (2b, 2c, 2g);
d) identify and explain the relationship among stream velocities, sediment load, and discharge (2c, 2e, 2f, 2h);
e) describe the factors determining the geometry of a river and identify segments where erosion and sedimentation occur (2c, 2f-2h, 5b).

2. Student Activities

Students are to:

*a) prepare a diagram of the hydrologic cycle as it applies to a drainage basin (5a);
*b) identify drainage basins on suitable topographical maps or in air photographs (5b);
*c) draw the profile of a trunk stream from suitable topographical maps and determine the stream gradient (5b);
d) prepare graphs to illustrate the flow duration and return period (recurrence interval) of a given river;
e) establish the relationship between stream velocities and sediment loads and determine the particle size of the transported sediment by taking measurements at a local stream;
f) establish the geometric properties of a meander and the segments of a meander where erosion and sedimentation occur (5b);
*g) classify various types of drainage basins on the basis of topographical control of the river system (5b);
h) classify various types of deltas, using topographical maps or air photographs (5b);
i) observe the development of a drainage basin, using a stream table.

3. Applications

a) An understanding of the fluvial processes within a drainage basin provides the basis for land-use planning, water conservation, and resource management.
b) The analysis of drainage basins provides the basis for determining the denudation of a continent.
c) Data derived from the study of drainage basins allow an assessment of the water supply of political units such as provinces and countries.

4. Societal Implications

a) A knowledge of the changes that have taken place over time in a drainage basin provides us with an understanding of many environmental problems.
b) A drainage basin provides the best geomorphic unit for land-use planning and for coping with changes brought about by urbanization.

5. Evaluation of Student Achievement

At least 40 per cent of the term mark for this unit is to be based on students':

a) proficiency in preparing diagrams of the hydrologic cycle;
b) proficiency in reading and interpreting drainage-basin information from topographical maps or air photographs.

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*See the subsection entitled "Student Activities" on page 5.

6. Safety Considerations

a) Students must obey the rules of water safety if they do a stream analysis.
b) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) research the development of a drainage basin, following the theories of Hutton or Davis;
b) analyse the stream orders of a drainage basin and establish the organization of the drainage net, using semilog graph paper;
c) investigate the relationship between laminar and turbulent flow and sedimentation;
d) write a report on the changes produced in a major drainage basin by dam construction on the trunk stream (e.g., the Bennett Dam on the Peace River);
e) discuss the issue of water sales;
f) investigate the problems associated with drainage basins that are divided by political boundaries;
g) identify the effects of urban activities on flood-plain areas;
h) investigate and evaluate the future plans for a watershed area.

8. Some Teaching Suggestions

a) Students could obtain data and illustrative material pertaining to the drainage basin in which the school is located.
b) Students could measure the stream velocities and discharge rates of a local stream.
c) A good selection of maps and air photographs should be available so that students, working in groups, have on hand comparative data for such topics as stream profiles, the forms of drainage basins, and meander analysis.
d) Copies of various government documents that have references to drainage basins (watersheds) should be obtained.

Optional Unit 6

Ground Water

Time: 6 hours

Ground water, the water beneath the earth's surface, is contained in pore spaces within the regolith and bedrock. As it is understood today, it is derived from precipitation, except for a very small amount that comes from substances within the earth's interior. Ground water is an important part of the hydrologic cycle. Too often, however, its presence as a renewable resource is taken for granted, and the effectiveness of the cycle becomes diminished when the withdrawal of water from the ground exceeds recharge. The purpose of this unit is to provide students with opportunities to review the hydrologic cycle; to study ground water and its chemistry, movement, and relation to the geological environment; and to understand the social and economic aspects of ground water.

This unit may be divided into topics such as the following:

- ▸ Review of the water cycle
- ▸ The composition of ground water
- ▸ The movement of ground water
- ▸ Geological work by ground water
- ▸ The social and economic effects of ground water

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a respect for the role that ground water plays in the maintenance of an effective hydrologic cycle;
b) an appreciation for the geological work carried out by ground water in its interaction with the earth's crustal rock;
c) a concern for the demands being placed on ground-water reserves;
d) a commitment to the conservation of not only ground-water resources but all natural resources.

Skills. Students will have the opportunity to develop skill in:

a) sketching the water cycle, the water table, artesian wells, and structures associated with the geological work of ground water (2a, 2e);
b) analysing the variables to establish ground-water behaviour (2a, 2c-2e);
c) applying the chemistry of ground water to its geological work (2e).

Knowledge. Students will be expected to:

a) define, within the scope of hydrogeology, the following terms: hydrologic cycle, aquifer, head, infiltration, permeability, porosity, percolation, saturation, aeration, water table, cone of depression, recharge, karst;
b) explain the role of ground water as a storage reservoir in the hydrologic cycle (2a);
c) describe how the movement of ground water is controlled by the physical properties of rocks (2b, 2c);
d) state the factors that govern the recharge of ground water (2a-2c);
e) recognize that a ground-water system is an open system and that each segment is in a state of dynamic equilibrium (2a);
f) state the effects of withdrawal of water from an aquifer (2b, 2c, 2f);
g) explain the role and the effects of ground water as a geological agent (2a, 2b, 2d, 2e);
h) describe the contribution of ground water to the base flow of a river (2a).

2. Student Activities

Students are to:

*a) sketch the hydrologic cycle and explain the role of ground water in the cycle (5a);
b) analyse various types of rocks to determine their porosity;
c) observe, through a simulation, the movement of ground water through sand;
*d) investigate the chemical properties of ground water that contribute to the geological work of ground water (5a);
*e) construct charts or labelled diagrams to explain the geological work of ground water (5a);
*f) gather information about excessive withdrawal of ground water from an aquifer, for example, the Ogallala aquifer of the American Great Plains (5b).

3. Applications

a) A knowledge of ground-water levels is a prerequisite of good ground-water management.
b) The development of karst topography is the result of the chemical action of ground water on carbonate rocks.

4. Societal Implications

a) According to the basic principle of conservation, the rate of withdrawal of ground water cannot exceed the rate of recharge.
b) The dissolving of carbonate rocks presents a geological hazard to people living in areas where this occurs.
c) Ground water is a significant factor in the distribution of vegetation and thus in desertification and erosion.

5. Evaluation of Student Achievement

At least 40 per cent of the term mark for this unit is to be based on students':

a) proficiency in sketching and explaining the hydrologic cycle and the geological work of ground water;
b) research into and presentation of an example of the excessive withdrawal of ground water from an aquifer.

6. Safety Considerations

a) Students should exercise care on field trips.
b) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) do a case study on the Bonnechere Caves of eastern Ontario or the Blue Mountain Caves of western Ontario;
b) visit a water-treatment plant to observe the purification of water under conditions similar to those underground;
c) visit a town that has a ground-water supply system to observe the techniques used to obtain the water;
d) explain the principles of fluid dynamics in a permeable medium.

8. Some Teaching Suggestions

a) Transparent dishes containing water coloured by ink and sand will illustrate the movement of water through sand.
b) A review of both the hydrologic and rock cycles would be beneficial at the beginning of this unit.
c) This unit lends itself well to the use of diagrams and graphs to illustrate the behaviour of ground water. There should be an emphasis on visual aids to help students understand ground water.

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*See the subsection entitled "Student Activities" on page 5.

Optional Unit 7

Geophysical and Geochemical Exploration

Time: 6 hours

The techniques of geophysical and geochemical exploration are a relatively recent development, becoming widely used in the 1920s. By the 1950s these techniques were responsible for most of the new finds that were being made. Today, with the target of exploration often lying under many metres of overburden, younger rock, or water, increasingly sophisticated techniques are needed to determine its location. The equipment used in geophysical exploration is designed to detect in rocks variations in such physical characteristics as specific gravity, magnetism, or the ability to transmit or reflect seismic waves. Geochemical techniques involve analysis for metal traces in soils, ground water, and vegetation. More recently, remote sensing, performed by both air and satellite equipment, has supplemented geophysical and geochemical methods. All of these methods use sophisticated computer techniques in the increasingly difficult search for new resources. The purpose of this unit is to provide students with opportunities to investigate the variety of techniques used in finding these new resources.

This unit may be divided into topics such as the following:

- ▸ Traditional geological methods of exploration
- ▸ Geophysical methods of exploration
- ▸ Geochemical methods of exploration

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for geophysics and geochemistry as tools for the exploration for resources (2a, 2b);
b) a respect for Canada's worldwide leadership in geophysics (2c);
c) an appreciation for the instrumentation used in geophysics, geochemistry, and remote sensing (2a-2c).

Skills. Students will have an opportunity to develop skill in:

a) explaining the instrumentation and techniques used in exploration (2a, 2b);
b) drawing sketches of the instruments and techniques used in exploration (2a, 2b);
c) using measurement, where possible, to construct tables, graphs, and maps to record data (2d);
d) drawing inferences from various data (2a).

Knowledge. Students will be expected to:

a) explain the following terms: geophysics, geochemistry, magnetometer, gravity meter, Geiger counter, scintillation counter, reflection, refraction, gamma sensitivity;
b) explain the principles of geophysical investigations (2a, 2d);
c) explain the principles of geochemical investigations (2b);
d) explain the principles of different types of remote-sensing instruments;
e) define the term *anomaly* and infer the basic characteristics of anomalous conditions (2a-2c);
f) determine which technique is best suited for the exploration of a given area (2a-2c).

2. Student Activities

Students are to:

*a) note and sketch the techniques of geophysical investigations (5a);
*b) note and sketch the techniques of geochemical investigations (5b);
*c) research the principles of remote sensing and remote-sensing instruments (5c);
d) plot seismic profiles from given data;
e) plot and interpret simple time-versus-distance curves.

3. Applications

a) Seismic, magnetic, electric, and electromagnetic principles are widely used in geophysical investigations.
b) Geochemical techniques are used in mineral exploration.
c) Remote sensing is playing an ever-increasing role in monitoring the earth.

4. Societal Implications

a) Industrial societies, with their dependence on resources, will place increasing demands on both geophysical and geochemical techniques to locate new sources of raw materials.

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*See the subsection entitled "Student Activities" on page 5.

b) Canada contains many raw materials, and geophysical and geochemical technology provides means of locating them.
c) Geophysical techniques (e.g., radiation and ultrasound) are now being applied by the medical profession in treating patients.

5. Evaluation of Student Achievement

At least 40 per cent of the term mark for this unit is to be based on students':

a) drawings and explanations of geophysical techniques;
b) drawings and explanations of geochemical techniques;
c) research into remote-sensing techniques.

6. Safety Considerations

a) If any specialized equipment is used, students should be instructed in correct and safe ways of using it.
b) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) study the life and accomplishments of a noted Canadian geophysicist;
b) test selected rock samples for conductivity or magnetic susceptibility, using an ohm meter, a dip needle, or a compass;
c) conduct a simple magnetic investigation, for example, searching with a compass for a large iron object that has been buried in the back of the schoolyard;
d) plot and interpret given electromagnetic data;
e) make inferences regarding an area after viewing different remote-sensing images of that area.

8. Some Teaching Suggestions

a) Tables and graphs should be used whenever they are appropriate.
b) It is important that all students take part in the activities.
c) The use of visual media to reinforce the different instruments and techniques used is beneficial.
d) Students should plot and contour geophysical data whenever this is appropriate.
e) Case histories should be used to illustrate different geophysical methods.

Optional Unit 8

Extraterrestrial Geology

Time: 6 hours

Humans have long nurtured the dream of visiting earth's neighbours in the solar system and beyond. This dream finally became a reality on July 21, 1969, when *Apollo 11* landed on the moon. From that landing and five subsequent ones, lunar material was brought to earth and subjected to the most intensive scrutiny ever conducted on rock samples. Since the planets and other members of the solar system are geological entities, it is entirely natural that geologists would turn their attention to these extraterrestrial bodies, basing their research on samples brought from the moon and meteorites, as well as on information gained from the vast array of remote-sensing techniques that are at the disposal of researchers today. The purpose of this unit is to provide students with opportunities to examine theories on the origin of the solar system and the geological characteristics of the planets and other members of the solar system, as well as to relate terrestrial geology to extraterrestrial bodies.

This unit may be divided into topics such as the following:

- The origin and dynamics of the solar system
- Solar structure
- The geology of the earth and moon
- Terrestrial and gaseous Jovian planets
- Asteroids, meteors, and comets
- Astronomical events on earth

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the earth as an extraordinary and wonderful planet;
b) an appreciation of the complementary nature of scientific research and space technology;
c) a curiosity about the heavens;
d) an appreciation of the vast amount of data collected by remote sensing, both from the earth and from space probes;
e) a questioning attitude with regard to the limitations of interpretations based on remotely sensed data.

Skills. Students will have the opportunity to develop skill in:

a) drawing inferences from observations (2c);
b) using appropriate techniques to observe the sun and the moon (2b, 2e);
c) classifying planets according to their physical characteristics (2c, 2e);
d) evaluating theories about the origin of the solar system (2a, 5a).

Knowledge. Students will be expected to:

a) explain the following terms: spectroscopy, meteor, meteorite, comet, asteroid, moon, shatter cone, tektite;
b) compare and contrast the different theories on the origin of the solar system (2a);
c) describe and explain the past, present, and future of the universe according to each of the three main cosmological theories (2a, 5a);
d) describe the structure of the sun in terms of its size, interior, and visible surface (2c, 5b);
e) differentiate between the terrestrial planets and the gaseous Jovian planets (2c, 5b);
f) explain the current theory of the moon's origin (2b, 2c, 5b);
g) compare the structure, both internal and external, of the earth and the moon (2a, 2c, 5b);
h) explain the current theory of comet origin and structure and the changes in the comet's appearance as its distance from the sun changes (2c, 2d);
i) differentiate among meteor, meteoroid, and meteorite (2c);
j) explain why comets and meteorites are of interest to scientists (2c);
k) describe and explain the effect on the earth of the following astronomical events: solar flares, meteorites, Van Allen belts (2d);
l) identify and explain the occurrence of tectonic activity in the solar system (2c, 5b).

2. Student Activities

Students are to:

*a) examine the current theories on the origin of the universe, solar system, and planets (5a);
*b) compare the geology of the moon to that of the earth (5b);
*c) prepare a report on the planets, major moons, and other members of the solar system (5b);
*d) sketch and explain the structure and characteristics of the sun (5b);
e) examine data on the heavens obtained by remote sensing;
f) plot star trails or meteors with a camera.

3. Applications

a) An understanding of planetary motion led to the deployment of satellites.
b) New technologies such as satellites provide new means of gathering information from space and new methods of collecting energy from the sun.
c) The remote sensing conducted by satellites supplies us with a vast and continuous flow of information about the earth and the heavens.
d) New knowledge gained from the study of the heavens allows scientists to gain a better understanding of the earth.
e) Celestial navigation and timekeeping rely on an understanding of the motions of the earth.
f) Civil time is largely based on the earth's motions.

4. Societal Implications

a) The theories of the origin of the universe and the earth developed by astronomers, philosophers, and theologians have helped to define our place in the universe.
b) Space technology has resulted in extensive benefits for humanity, even though the exploration of space is motivated, to a large extent, by military considerations.
c) Significant astronomical events may have been responsible for mass extinctions over geological time.

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*See the subsection entitled "Student Activities" on page 5.

5. Evaluation of Student Achievement

At least 30 per cent of the term mark for this unit is to be based on students':

a) written reports dealing with the origin of the universe and the solar system;
b) comparisons of the geology of the earth and the moon and of the sun and the planets.

6. Safety Considerations

a) Students must not look directly at solar eclipses or the sun with the naked eye, a telescope, or binoculars.
b) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) study the contributions of Keppler, Tycho Brahe, Newton, Copernicus, Galileo, Bode, or Einstein;
b) build a model of the orbit of a comet;
c) build a scale model of a large terrestrial volcano such as Mauna Loa, a large moon crater, or Nix Olympica;
d) research the mystery surrounding tektites;
e) research Halley's Comet;
f) observe the moon and one or two of the planets;
g) photograph star trails or meteorites;
h) discuss the problems associated with making contact with possible extraterrestrial intelligence.

8. Some Teaching Suggestions

a) Astronomical news items from magazines or newspapers are valuable resources for the classroom.
b) It is important to use visual media to reinforce the characteristics of celestial objects.
c) Plans could be made to observe items on selected nights or to observe special astronomical events as they occur.
d) A trip to a planetarium, where possible, is recommended. Where this is not possible, films can be used to supplement the program.
e) Members from a local astronomy centre or club could be invited to make a presentation to the class.
f) Tables and graphs should be used as resources whenever appropriate.

Optional Unit 9

Locally Designed Unit

Time: 6 hours

This unit is to be designed at the local level as desired. It can be used to introduce a new area or topic of science not described in this guideline or to incorporate additional objectives that will expand a part or parts of the course already covered. The following are examples of new areas or topics that might be considered:

- A unique geological structure
- A unique local geological activity
- Careers in the earth sciences
- Environmental geology and pollution
- Geological notes for a road section
- Milling, smelting, and refining
- Mineral resources in the ocean or on the ocean floor
- Prospects and claims

While this unit may provide an excellent opportunity for students to engage in independent study on a topic in science that is of particular interest to them, their work should be approved, monitored, and evaluated by the teacher. Students may work individually or in small groups. Care should be taken not to allow the work to overlap with subject matter in other science courses that the students have taken or are likely to take. The unit should be started only after students have had some experiences in the laboratory and are well aware of accident prevention. If a series of short topics is considered, the topics may be fitted into the course schedule from time to time throughout the semester or year.

A locally designed unit is to incorporate components similar to those adopted in the core units, namely, objectives, student activities, applications, societal implications, and safety considerations. A description of the unit is to be included with the school's course outline and kept on file so that it is available to interested students and parents.

Appendixes

Appendixes

A. Science Courses and Their Course Codes

B. The Table of Contents of Part 1

Appendix A

Science Courses and Their Course Codes

The secondary school guideline courses in science authorized under this document have the following course codes:

Science, Grade 9, Basic Level	SNC1B
Science, Grade 9, General Level	SNC1G
Science, Grade 9, Advanced Level	SNC1A

Science, Grade 10, Basic Level	SNC2B
Environmental Science, Grade 10, General Level	SEN2G
Science, Grade 10, General Level	SNC2G
Environmental Science, Grade 10, Advanced Level	SEN2A
Science, Grade 10, Advanced Level	SNC2A

Science, Grade 11, Basic Level	SNC3B
Applied Biology, Grade 11, General Level	SBA3G
Applied Chemistry, Grade 11, General Level	SCA3G
Environmental Science, Grade 11, General Level	SEN3G
Biology, Grade 11, Advanced Level	SBI3A
Chemistry, Grade 11, Advanced Level	SCH3A

Science, Grade 12, Basic Level	SNC4B
Environmental Science, Grade 12, General Level	SEN4G
Geology, Grade 12, General Level	SGE4G
Applied Physics, Grade 12, General Level	SPA4G
Environmental Science, Grade 12, Advanced Level	SEN4A
Geology, Grade 12, Advanced Level	SGE4A
Physics, Grade 12, Advanced Level	SPH4A
Technological Science, Grade 12, General Level	STE4G

Biology, OAC	SBI0A
Chemistry, OAC	SCH0A
Physics, OAC	SPH0A
Science in Society, OAC	SSO0A

The following general rules govern science course codes:

- All science course codes begin with an **S**.
- **SNC** identifies a course that has only the name "Science".
- Where one word other than "Science" describes the course, the first two letters of that word follow the **S** (e.g., **SBI** means "Science, Biology" or simply "Biology"; **SEN** means "Science, Environmental" or "Environmental Science").
- Where two words other than "Science" describe the course, the initial letters of those words are used (e.g., **SCA** means "Science, Chemistry Applied" or simply "Applied Chemistry").
- The fourth character in the course code, **1**, **2**, **3**, **4**, or **0**, represents Grade 9, 10, 11, 12, or an OAC respectively.
- The fifth character represents the level of difficulty: **B** for basic, **G** for general, or **A** for advanced.

For further information on course codes, refer to the *Manual for the Common Course Code* (Toronto: Ministry of Education, Ontario, 1986).

Appendix B

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88-059

ISBN 0-7729-2415-5

© Queen's Printer for Ontario, 1988